AFIT/GEE/ENS/94S-02

DEVELOPMENT OF AN ANALYTICAL HIERARCHY PROCESS (AHP) MODEL FOR SITING OF MUNICIPAL SOLID WASTE FACILITIES

THESIS

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AFIT/GEE/ENS/94S-02

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THESIS TITLE: DEVELOPMENT OF AN ANALYTICAL HIERARCHY PROCESS(AHP) MODEL FOR SITING OF MUNICIPAL SOLID WASTE FACILITIES

DEFENSE DATE: 05 AUG 94

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THESIS

Presented to the Faculty of the School of Engineering

of the Air Force Institute of Technology

Air Education and Training Command

In Partial Fulfillment of the Requirements for the Degree of

Master of Science in

Engineering and Environmental Management

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Captain, USAF

September 1994

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Preface

The purpose of this study was to determine and apply a Multi-criteria decision making methodology to select a process of disposing municipal solid waste. The task required an enormous amount of literature review and qualitative analysis. Fortunately, the expertise and support were found in my thesis committee, faculty, family, and friends.

One of the important crossroads of this study was defining the research problem and identifying the scope and objectives of the research. In this area, a great amount of assistance was received from Mr. Merritt Wichner and Ms. Debra Needham, both affiliated with the Clark County Solid Waste District. I thank both of them for their great insights and support of the entire effort.

The whole ordeal has been a valuable and enjoyable experience. This would not have been possible without the attention and reassurances of my advisor, Professor Yupo Chan, Ph.D., P.E. and reader, Major Jim Aldrich, Ph.D. They provided me with the tools and the proper perspective to get the most out of this effort. I thank them for their patience and unending support.

Most of all, I thank my lovely wife--Patricia, and two sons--Christopher and Andrew. They served as my beacon and provided the spark of motivation throughout the entire program. I greatly appreciate their show of patience, understanding, and support.

Lastly, but definitely not the least, I thank God for his guidance throughout this challenging but worthwhile experience. *Lord, guard and guide...*

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Abstract

Deciding on locations for municipal solid waste facilities is a difficult problem where qualitative criteria compete with quantitative economic and engineering criteria, in an environment that is highly political and emotional. State guidelines often describe different methodologies but fall short in offering a solution or a methodology in arriving at a solution. This study develops a decision modeling procedure, based on the Analytical Hierarchy Process (AHP), that can be used by public sector decision makers to locate and site municipal solid waste facilities. The applicability of the procedure is demonstrated at the City of Springfield, Clark County, Ohio.

Research efforts included review of alternatives to dispose municipal solid waste and multicriteria decision making techniques with potential application to the problem. Due to the nature of the problem, the Analytical Hierarchy Process was selected. A hierarchy was then developed and the Clark County Solid Waste District Coordinator provided inputs that best approximated the decision maker's inputs to arrive at a solution.

Final results suggest that current disposal methods of disposing waste should be continued (transfer facility). However, as cost continues to increase relative to the given alternatives, a detailed investigation is required to determine the viability of an incinerator or a landfill, in that order.

AN ANALYTICAL HIERARCHY PROCESS(AHP)

MODEL FOR SITING OF

MUNICIPAL SOLID WASTE FACILITIES

I. Introduction

Ever since the discovery of fire, man has polluted the surrounding air. (15:65) Man used fire to cook food, provide heat, and occasionally burn refuse. The voluminous amount of air in the atmosphere and its constant motion allowed the dispersion of the relatively small amount of what we now call air pollution. (15:65) Man took this act for granted and as time progressed, the use of incineration as a method of municipal solid waste (everyday house-hold trash) disposal increased in the development of our industrialized and modern cities.

In addition to incineration, landfilling has also been a widely accepted method of disposing municipal waste. The U.S. Environmental Protection Agency reported in 1988 that 80 percent of the nation's municipal waste is landfilled. Landfilling, however, has met numerous scrutiny as a result of ground water contamination, public disturbance during transport, and environmental degradation. An example is the on-going and costly issue of ground water remediation from past landfills at Wright-Patterson Air Force Base in Dayton, Ohio.

Another method of dealing with municipal solid waste is recycling. As communities, businesses, industry, and government battle the rising costs and face environmental impacts of waste disposal, recycling has surfaced as a potential alternative of solving the ever-growing municipal solid waste issue. In a presentation to a group of environmental managers on March 1994, Colonel Marcos J. Madrid, Chief of Environmental Programs at Air Combat Command, highlighted recycling to include that of municipal solid waste as a major agenda in the Command's Pollution Prevention program. Numerous counties in the country like Greene and Clark County, Ohio and Ventura County, California have already established and implemented various recycling programs.

Another breakthrough in municipal waste management is the use of an aerobic degradation process by which plant and other organic wastes decompose under controlled conditions--better known as **composting**. This process, however, poses several environmental concerns. As Captain Tim Merrymon states in his thesis regarding the viability of composting, "the main problem with composting municipal solid waste revolves around the Resource Conservation and Recovery Act (RCRA). Because of its exemption of household wastes, anything can be picked up by municipal waste haulers"--including pesticide containers, cleansing agents, paint product residues and other potentially hazardous materials. (28:11) This exemption leads to increased costs for seperation and potential liability costs. Although an alternative to the municipal waste issue, composting poses environmental concerns.

Finally, and perhaps the ultimate solution to the problem is elimination, or more realistically--reduction of the source. The above-mentioned methods rely on tackling the issue after-the-fact. Historically, waste management has been an end-of-pipe (after the product becomes waste) activity. Source reduction, on the other hand, emphasizes the reduction of waste at the source to prevent expenditure of countless time, money, and effort on waste disposal. There was a time when almost all U. S. Air Force bases had one or more landfills on the installation. Since then, more stringent regulations and more efficient alternatives have enabled us to nearly get out of the landfill business altogether. In most instances, the solid waste of a military installation is disposed at the same location as the local community for which that base is located. It is therefore imperative that bases play an active role in the community's municipal solid waste agenda. As mentioned by Mr. Robert Kemether, Program Manager for Solid Waste Management at Air Combat Command, "we must now explore all options available to work closely with the state and local community in reducing our solid waste." (1:335) Clearly, the solution to the municipal solid waste problem is to reduce, if not eliminate, the source. Source reduction and recycling initiatives should also be implemented. Both of these methods, source reduction and recycling, are inherent to dealing with municipal solid waste. Others, as mentioned above, include incinerators, landfills, and composting yards. Since source reduction and recycling are inherent to any municipal solid waste disposal program, focus of this research is placed on the following sited facilities: incinerators, landfills, and compost yards.

Before a method of disposal is selected, it is important to first determine the facility's appropriate location. This in itself offers several multiple conflicting factors in the decision-making process. Several facility location models have been published in the literature and applied in day-to-day applications. Such models include covering models, median or minisum models, and center or minimax models. (18: 89) Application of such models for a specific facility, however, is beyond the scope of this study. Once locations of facilities have been determined, a location/facility and hence a method of disposal can then be chosen from a given set of quantitative and qualitative criterias.

Clearly, the management of municipal waste is a complex undertaking. From large metropolitan areas such as New York or Chicago to smaller communities like a typical Air Force base, the disposal of municipal waste has been a hotly debated issue. Decisions regarding solid waste disposal systems and its location which are often referred to as obnoxious facilities pose unique complexities. There are generally a large number of somewhat powerful stakeholders as well as a relatively large number of decision makers with strongly opposing objectives. Political, social, personal, and economic issues play key roles in determining the outcome of the decision. In short, decisions regarding implementation of a sound municipal solid waste plan in a given community is often made with competing objectives--if not without careful coordination with the aforementioned issues. Ultimately, decisions are often viewed as driven by budget constraints and outspoken political groups.

Research Problem

Given the complexity of the decision-making process for a municipal solid waste management plan, the task of determining an appropriate method of disposing municipal solid waste is challenging to say the least. Additionally, the siting of municipal waste disposal facilities that predicate this rigorous process is an even more difficult task. A decision support model utilizing multicriteria decision making techniques will significantly aid decision makers in developing sound and defensible policies.

Research Objectives

The purpose of this research is to determine and develop a decision support model utilizing multicriteria decision making techniques in determining an appropriate municipal solid waste plan for a given community. This model will be applied and validated at Clark County with the aid of the Clark County Solid Waste District office. In order to accomplish this task, research efforts will focus on current multicriteria decision making methodologies and the development of a model that will aid in the selection of a municipal solid waste plan for a given community from a given set of alternatives for a given community.

Scope Limitation

As mentioned above, the siting and selection of a municipal solid waste facility is a complex undertaking. An attempt to answer the broad scope of this issue will take an insurmountable amount of time. Therefore, this effort will only encompass the selection of a particular methodology and the development of a model after the siting of specific facilities is completed through the application of various location models. Using operational research and other quantitative and qualitative methods, specifically multicriteria decision making, this project will formulate a model that lays the groundwork for choosing a program from a given set of efficient alternatives that a community or region can use in the management of its municipal solid waste. This involves the determination of critical factors and the establishment of trade-off values to rank order possible alternatives.

Organization of the Research Report

The first step in developing an appropriate multicriteria decision making model for rank-ordering alternatives dealing with municipal solid waste is to understand the broad scope of the municipal solid waste program and its salient features. This includes a general discussion of incineration, landfilling, and composting. Additionally, an understanding of multicriteria decision making techniques and their application in the field is tantamount in model development. The Literature Review accomplishes this objective. Following the Literature Review, a methodology will be discussed in the formulation of the model in Chapter 3. The Analytical Hierarchy Process (AHP), sometimes referred as a subset of the Multi-Attribute Utility Theory, will be applied to select an appropriate method of disposing municipal waste. Finally, an analysis and summary of findings is included in Chapter 4 with Conclusions and Recommendations for further study incorporated in Chapter 5.

II. Literature Review

In an effort to better understand the topic and select an appropriate methodology in model development, this chapter presents a review of some of the literature applicable to municipal solid waste, its current management philosophy, multiple criteria decision making techniques and their potential application in municipal solid waste management. First, an introduction that highlights certain aspects of municipal solid waste and the general background of multi-criteria decision making is presented. A review is then extended to multi-criteria decision making principles which may have municipal solid waste management application.

Introduction

The relatively new environmental arena was marked by the birth of the "Environmental Revolution" through the creation of the United States Environmental Protection Agency (US EPA) in 1970. Initial focus was management of numerous uncontrolled hazardous wastes. Events such as those involving the Hooker Chemical Company and Occidental Chemical Corporation in New York (Love Canal incident); the ABM-Wade site in Chester, Pennsylvania; and others further heightened public interest in the environment. (4:1-18) This initial focus quickly transgressed into other environmental issues like water pollution and air pollution. But none has greater impact on everyday life as the issue of municipal solid waste.

Decisions regarding the appropriate disposal of municipal solid waste are often made amid opposing objectives and perspectives. Various groups with competing objectives, both quantitative and qualitative, lobby to have their opinions heard at different forums. This situation sets the stage for what might appear to be a haphazard decision regarding the disposal of municipal solid waste. Although subjectivity is inherent in the decision-making process, a decision support tool would result sound decisions and defensible policies.

Environmental Background

Municipal solid waste may sometimes be coined as "garbage" in day-to-day vernacular. As the U.S. Environmental Protection Agency defines municipal solid waste in its **Decision-Makers Guide To Solid Waste Management**, municipal solid waste:

> includes non-hazardous waste generated in households, commercial and business establishments, institutions, and light industrial process wastes, agricultural wastes, mining waste and sewage sludge. In practice however, specific definitions vary across jurisdictions (33:152).

It is evident that the composition of municipal solid waste is varied from a wide-ranging array of industries. The U.S. Environmental Protection Agency suggests that the 1988 composition of municipal solid waste in the United States included 40% paper, 25% food and yard waste, 8.5% metals, 8% plastics, 7% glass, and 11.5% miscellaneous to include durable goods. (24: 6)

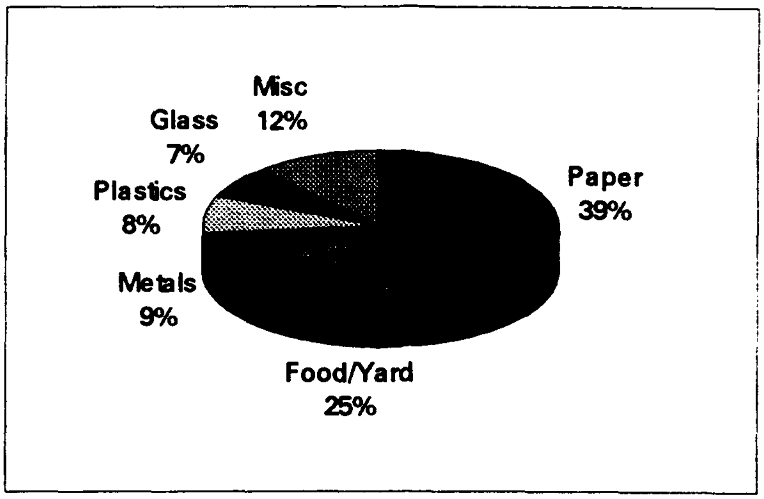

Figure 1. Composition of Municipal Solid Waste (1988) (taken from Liptak, p. 6)

From the categories mentioned and shown above, it is clear that each and every one of us, in one form or another, deal with municipal solid waste. It is also important to note that the quantity of municipal solid waste generated per person per day from 1965 to 1986 nearly doubled. (24:10) In light of this fact, Americans continue to produce more and more solid waste each year...more so than any other nation in the world. (12: iv) That's 160 million tons of municipal waste each year! (12: 3) As we generate more waste, the "environmental revolution" has also placed stringent rules regarding waste disposal, thus limiting disposal alternatives. Landfills in parts of the nation have reached their saturation point. Existing incinerators continue to be challenged by strong opposition. Overall, new solid waste facilities continue to face difficulty in siting due to public resistance. The national attention now focuses on the potential crisis in municipal solid waste management. The roving garbage barge from Islip, New York wandering from port to port in search of a place to dispose of its load has become a symbol of our solid waste dilemma, and the "garbage gap"--the discrepancy between our growing volume of municipal solid waste and the capacity to deal with it--is a media catchword.

In response to a clear need for national leadership in facing our solid waste management challenges, the U.S. Environmental Protection Agency created the Municipal Solid Waste Task Force in 1988. Working with interested groups from all sectors of society, the Task Force developed a national strategy for improving the management of municipal solid waste. The result was a publication entitled **The Solid Waste Dilemma: An Agenda for Action** in 1989 which included inputs from the general public, interested trade associations, environmental groups, and government organizations.

At the same time, the House Committee on Energy and Commerce, the House Committee on Science, Space, and Technology, and the Senate Committee on Environment and Public Works, in anticipation of the reauthorization of the Resource Conservation and Recovery Act (RCRA), requested a study on municipal solid waste. The resulting publication later that year, **Facing America's Trash, What Next for Municipal Waste?** outlines options for a national policy based on dual strategies of municipal solid waste prevention and better management.

Both studies concluded that the municipal waste challenge required aggressive and proactive measures. The studies conclude that in order for our society to tackle this dilemma, the society as a whole need to develop a culture change emphasizing a concept of source reduction. In other words, we need to reduce the amount of waste generated. Additionally, once society have minimized the amount of generated waste, an ideal method of waste disposal can then be implemented. These municipal waste management methods, according to the reports include landfilling, incineration, and composting.

Incineration. Incineration, as defined by Denison and Ruston, is not a waste disposal method but rather a waste processing technology. (6: 172) They refer to incineration as a process rather than a disposal since incineration produces ash which still requires disposal. Nonetheless, incineration is a process of dealing with municipal solid waste. These technologies include rotary kiln incineration, fluidized bed incineration, liquid injection incineration, and infrared incineration to name a few (20)--each with its advantages and disadvantages. As a whole, incineration provides the benefit of reducing the amount, particularly the volume of waste requiring disposal to as low as 5-10% of raw refuse volume. Incinerators can also produce energy in the form of steam, hot water, or electricity which can provide a revenue source to offset operating costs. On the other hand, incineration creates air pollution concerns and produces potentially toxic ash residues that must be managed and disposed properly. Additionally, initial cost to construct and permit an incinerator are exorbitant. Liptak suggests that the cost of an average incinerator, one that serves a population of 500,000 and burn up to 1,000 tons of municipal solid waste per day, was a whopping $125 million in 1991. (24:92)

Composting. Composting refers to the controlled process of decomposing organic material into a stabilized humus. Composting alters a component of the waste stream through a degradation process into material that can perhaps be used as a soil alternative. Results of composting may include the mass and volume reduction of disposed waste thus affecting the capacity of existing and proposed disposal facilities. Composting can also be performed on yard or landscape waste and processed components of municipal waste. According to Charles Cannon, executive vice president of the Solid Waste Composting Council, "as much as 60 percent of the nation's garbage could be composted, including disposal diapers, soiled paper wrappers and thrown-out foods as well as grass, leaves, and branches". (28:10) Other figures like Taylor and Kashmanian's 1988 study indicate that compostable waste volume can be reduced up to 85 percent as a result of the composting process. (33:81) However, potential impacts such as environmental factors, level of technology, composting rate, markets, odor, and leachate must be addressed during the planning and development phases of a composting facility.

Landfills. As mentioned above, municipal solid waste can be incinerated or composted, and waste can be reduced by source reduction and recycling. However, residue from these methods still requires disposal. Landfilling is currently the ultimate disposal method for this residue and is therefore a necessary component of any municipal solid waste management system. The Office of Technology Assessment refers to landfilling as the disposal of waste on land in a series of compacted layers and covering it, usually daily, with soil or other materials such as compost. (12:271) Many communities, however, now face strong opposition to landfill siting. (33:107) As old facilities reach their useful life, a "capacity crises" -- increasing quantities of waste coupled with decreasing disposal capacity -- exists. If current trends continue, the number of landfills will be reduced by as much as 80 percent from 1988 to 2008. (See Figure 2) (12: 271) With the number of landfills decreasing, cost continues to escalate. (See Figure 3)

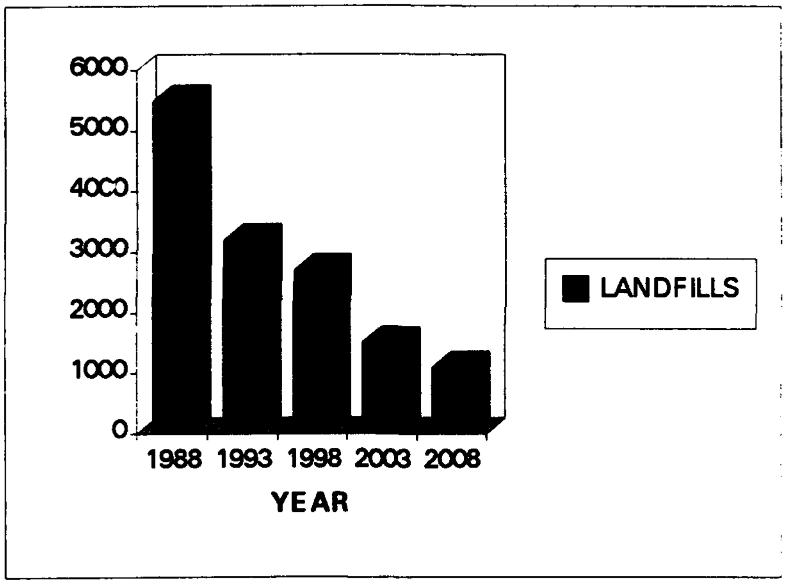

Figure 2. Estimated Number of Active Landfills in the Future ([US Congress, Office of Technology Assessment, 1989:273] taken from [EPA, 1988a])

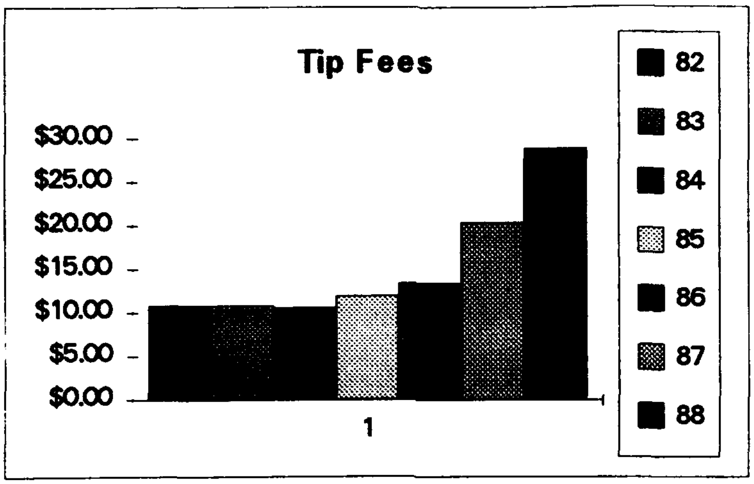

Figure 3. Tip Fees per ton (1982-1988)

Current Methodology

Current methodologies regarding municipal solid waste facility selection and siting are broadly outlined in state and district Solid Waste Management Plans. Ohio, for example, empowers that responsibility to its Solid Waste Districts. Districts then publish a District Solid Waste Management Plan that outline instructions for inventories, population and waste generation projections, management strategies, and methods of management...among other things. (29)

Focusing on facility selection and siting, such plans only call for an explanation of a strategy for the siting of new and expanded facilities. These plans also call for the siting strategy to:

- identify individuals or groups responsible for each step of the process;
- provide the estimated time required for each step; and
- be well defined so the process can be easily followed.

Additionally, plans call for the development of a ranking scheme to allow districts to compare potential sites quickly and as objectively as possible (29:45-46). Despite its attempt to provide clear guidance, such plans fall short in defining a methodology to accomplish this task. It merely hands over the responsibility to the local government to determine and support its selected methodology. Furthermore, plans suggests that an impasse should be resolved through mediation. This approach is generally formal, and brings together a limited number of representatives of opposing positions to work with a mediator toward resolution of conflicts.

Management Science Background

Selecting an appropriate disposal method for municipal solid waste is difficult. Without a clear and definitive directive, local communities are faced with tough decisions regarding its municipal solid waste issues. To answer the question of whether to have a landfill, incinerator, or pursue other alternatives is a difficult undertaking. Fortunately, a relatively new field called multicriteria decision making from the Management Science/Operational Research (MS/OR) environment is on the rise and can greatly aid in this tough decision making process. Multicriteria decision making had its beginnings in 1961 with such contributions like goal programming by Charnes and Cooper. (8: 645) Other contributions followed from Lee (1972), Igniziu (1976), Yu and Zeleny (1975), Zionts and Wallenius (1976) and many others. (8:645) Although such names may be trivial to most readers, these individuals pioneered the multicriteria decision making field and provided the cornerstone in today's methodologies.

Decision making is almost a routine event in everyone's lives. For example, the decision of the clothes we wear or activities we engage in is an everyday occurrence. While some decisions may not require a thorough analysis, situations may arise where the impacts are great and thus require a complete and thorough analysis. As an example, the siting of an airport requires the consideration of such criterias as location, cost, and travel distances. (22) As Yu eloquently describe, good decision making is based on three basic patterns of logic: simple ordering, human goal setting and goal seeking behavior, and value maximization. (36:3)

In the topic of simple ordering, Pareto optimality is an often associated term. Yu states that a good decision is selecting the best alternative that is the best in every aspect of consideration. (36:3) Methodologies such as linear programming, multiple-criteria (MC) simplex , and multiple-criteria and multiple-constraint (MC^2) simplex have been developed. These methodologies involve the identification of non-dominated solutions. Recent studies, such as: Baaj, Ashur, and Anwar (1994) (2); Huang, Baetz, and Patry (1993) (19); and Drezner and Wesolowsky (1985) (7); utilize modified forms of linear programming. These studies considered factors such as transportation costs, population disturbance, operation cost, capacity, and distances to population centers. All involve, in one form or another, a set of quantifiable criteria.

Secondly, human goal setting and goal seeking behavior highlight the concept of satisficing solutions. Satisficing solutions relate to mathematical programming which indicate that a particular alternative meets the desired criteria, but is not necessarily the optimum choice or ideal solution. (26:2-3) In other words, an alternative with the minimum(or maximum) distance to a predetermined ideal solution is deemed to the best alternative. Published papers such as those of Melachrinoudis and Cullinane (1986) (27), and Dasarathy and White (1980) (5), highlight such concepts as maximizing or minimizing "Euclidean distances" from a predetermined ideal solution. Yet another method is that of interactive approach (also known as Frank-Wolfe algorithm or Geoffrion, Dyer, Feinberg (GDF) method) . This method assumes that a large step-gradient ascent algorithm would be applicable if the decision maker were somehow able to specify an overall "preference function" to resolve the conflicts in the given multiple criteria, but never requires this preference function to be identified explicitly. In other words, this method adopts a mathemetical programming technique, but requires only the required information from the decision maker concerning his/her preferences over the criteria. (13:357) These studies considered municipal solid waste criterias such as pollutant impacts, distances, and transportation costs.

Thirdly, value maximization is selecting the best alternative that offers the best value. As McPherson describe, "value based techniques use the concept of utility, where utility is defined as the subjective benefit derived by the decision maker from the achievement of the stated goods or objectives." (26:2-5) At the forefront of this concept is Multi-attribute utility theory (MAUT). Ralph L. Keeney, sometimes regarded as one of the founding fathers of value based thinking, emphasized the importance of value in decisionmaking. (22) Ellingson and Gallogly utilized multi-attribute theory in developing a decision makers value function regarding the clean-up of hazardous and toxic wastes. (9) The Analytical Hierarchy Process, which is sometimes classified as a multi-attribute theory approach, was developed by Saaty in the mid-70's. Works by Haghani (1992) (18), Erkut and Moran (1991) (10), Kjelgaard et. al (1990)(23), and Kathawala and Gholamnezad (1987) (21) demonstrate the Analytical Hierarchy Process in practical applications. Compilation of other practical applications can be found in **The Analytic Hierarchy Process: Application and Studies** by Golden et al.

Another technique that warrants mention is the Delphi process. The Delphi process is a technique that involves soliciting and comparing anonymous judgments on the topic of interest through a set of sequential questionnaires interspersed with summarized information and feedback of opinions from earlier responses. (14:621) Basic differences of the Delphi to AHP are (1) anonymity of Delphi versus operating group discussion, (2) adjustment is a series of rounds in Delphi versus dynamic discussion, (3) questionnaire versus hierarchy structure as a basis for judgments, and (4) statistical and quantitiative analysis versus qualitative analysis. (31:69-70)

The real world issue of locating an undesirable facility, as stated by Erkut and Moran, is clearly a multiobjective decision problem. (11:288) They further add that this is a more complex problem than locating a service facility because of the perceived disutility surrounding the location of an undesirable facility. (11:288) Social acceptability is commonly the single-most important factor in determining the location of such facilities. This is especially the case when the effort is led by the public sector because political imperatives are of paramount importance for the majority of the decision makers. (10:90) Environmental consciousness emerged as a focus of attention as a result of potential disruption and damage to wildlife in the 1960's. (10:90) Today, the existence of adequate site drainage, absence of erodible materials, concern for air quality and groundwater contamination, and effects on wildlife habitat, and other environmental issues, must now be included in the site selection process.

Issues regarding this particular dilemma involve several conflicting quantitative and qualitative objectives. Given the public setting, the approach should also be relatively easy to follow and understand because of public participation. Thus, the approach should also incorporate the inputs of multiple decision makers who may have different agendas and objectives. (10:90)

Summary

The Analytical Hierarchy Process, because of its relative simpleness and popularity, appears to be a feasible method in determining the appropriate disposal of the municipal solid waste. It allows the treatment of a complex problem that involves both quantitative and qualitative factors within a context of a relatively simple decision framework. This is important when dealing with such varied issues in the public eye. Not only does the methodology have to be sound but easily used and understood by the public who may come from very diversified backgrounds. Haghani writes, the Analytical Hierarchy offers "tremendous advantages in its simplicity of application, its ability to deal with qualitative objectives, and its theoretical ability to deal simultaneously with as many objectives as desired. (18:91) Kathawala and Gholamnezad also add that it offers a method of breaking down a complex, unstructured situation into its component parts--arranging these parts, or variables, into a hierarchic order; assigning numerical values to subjective judgments , and synthesizing these judgments to determine the overall priorities of the variables. Furthermore, they add that the Analytical Hierarchy Process provides an effective structure for group decision-making by imposing a discipline on the group's thought process. (21:390) The group is often able to clarify misunderstandings and differences in interpretation of the data so that there is a more uniform understanding of the facts. (10:94)

III. Methodology

Introduction

This chapter outlines the procedures used in applying the Analytical Hierarchy Process in the development of a multicriteria decision model to determine an appropriate location and method of disposing municipal solid waste. Given the nature of the problem and time constraints for the research, this section applies the Analytical Hierarchy Process to rank order and prioritize given efficient alternatives or solutions. As described in the Literature Review, there are several methods aside from the Analytical Hierarchy Process. This section will describe and apply the Analytic Hierarchial Process.

Description of the Analytical Hierarchy Process (AHP)

Development. Thomas L. Saaty developed the Analytical Hierarchy Process in 1971-1975 while at the Wharton School (University of Pennsylvania, Philadelphia, Pennsylvania) in response to military contingency planning and the need for political participation in negotiated disarmament negotiations. (32: v) He subsequently published his first book on the subject in 1980 titled **The Analytical Hierarchy Process**. Since then, a plethora of publications have appeared in the literature. Specific examples include special issues in **Socio-Economic Planning Sciences**, and **Mathematical Modelling**.

Application of the Analytical Hierarchy Process is not limited to the United States. Studies have been cited from China(25) to Russia(35) covering wide-ranging topics from drug efficacy evaluation(3) and wine/tea tasting to relay-race team selection and university selection. (34) These examples underscore a pivotal aspect of the Analytical Hierarchy Process--its practical usefulness in day-to-day applications.

Dr. Saaty's initial drive to develop such a process arose from the need to solve complex problems that incorporate both tangible and intangible factors. The Analytical Hierarchy Process is a coherent theory that deals with both tangible and intangible factors without compromising one or the other. (32:161) This process structures a hierarchy of criterias, stakeholders, and outcomes. It also develops priorities by eliciting judgments from decision makers. As seen from the name of the method, the Analytical Hierarchy Process has three distinct components: ***analytic, hierarchy, and process.***

Analytic Description. As defined in the World Book Dictionary, analytic refers to separating a whole into its parts. Decision making involves choices and is often complex and hard to understand. Mathematics is an ideal way to understand and describe choices to others. As Patrick Harker puts it, "the Analytical Hierarchy Process uses numbers" because it utilizes logic and mathematical reasoning. Analytics, therefore, is an important part in the decision making process. (17:13)

Hierarchy Description. The dictionary defines hierarchy as an organization of persons or things arranged one above the other according to grade, order, or class. This refers to the break-up of a complex problem into "bite-size" pieces which can be tackled in a less complicated way. As Harker again describes it, by breaking the problem into [less complicated] levels, a decision maker can focus on a smaller set of [simpler] decisions. (17:13) This involves, however, a thorough understanding of goals, criterias, subcriterias, and alternatives.

Process Description. Decisions are generally not made "by-the-seat-of-your-pants". It requires a thorough understanding of the facts and often times involves inputs from several key players. Information is gathered, positions are negotiated, and finally decisions are made. Decision making is not a one-step process. Rather, decision making is an iterative process. The Analytical Hierarchy Process incorporates this iterative process to aid, thus shortening, the painstaking decision-making process.

Theoretical Underpinnings

A thorough expalanation of the principles that guide the Analytical Hierarchy Process is written in an article by Roseanna W. Saaty in **Mathematical Modelling**. She asserts that the three principles that form the basis of the Process include decomposition, comparative judgments and systhesis of properties. (32:166) To simplify in expository prose, the following is a simplified explanation of the theory taken from **The Analytic Hierarchy Process: Applications and Studies**:

Axiom 1 (Pairwise comparisons)

Given any two alternatives (or sub-criteria) i and j out of a set of alternatives A, the decision maker is able to provide a pairwise comparison a_{ij} of these alternatives under any criterion c from the set of criteria C on a ratio scale which is reciprocal; i. e.,

$$a_{ji} = 1/a_{ij} \quad \text{for all} \quad i, j \in A$$

This axiom suggests that if a decision maker in a pairwise comparison is able to make a statement that A is four times better than B, then the reciprocal of the statement is true--B is 1/4 th as good as A. This axiom is what Harker calls the "heart" of the Analytical Hierarchy Process--the ability to make paired comparisons of objects with respect to a common goal or criteria. These paired comparisons are then arranged in a matrix to arrive at an eigenvalue solution.

$$\begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} & a_{15} \\ a_{21} & a_{22} & a_{23} & a_{24} & a_{25} \\ a_{31} & a_{32} & a_{33} & a_{34} & a_{35} \\ a_{41} & a_{42} & a_{43} & a_{44} & a_{45} \\ a_{i1} & a_{i2} & a_{i3} & a_{i4} & a_{ij} \end{bmatrix}$$

Figure 4. Matrix table from paired comparisons

Axiom 2

When comparing any two alternatives $i, j \in A$, the decision maker never judges one to be infinitely better than another under any criterion $c \in C$; i.e.,

$$a_{ij} \neq \infty \text{ for all } i, j \in A$$

This axiom, again according to Harker, is vital to the process. Simply, it states that infinite preferences are not allowed. If a preference is infinitely preferred over another, there is really no choice. The answer is clear for that particular criterion and thus can be labeled as a "no-brainer."

Axiom 3

> ***One can formulate the decision as a hierarchy.***

This axiom states that a decision problem can be decomposed and structured in such a way to reflect a hierarchy of criterias, sub-criterias, and alternatives. Therefore, the overall goal is at the top of the hierarchy, followed by the sub-criterias, and finally the alternatives.

Axiom 4

> ***All criteria and alternatives which impact the given decision problem are represented in the hierarchy. That is, all the decision makers intuition must be represented (or excluded) in terms of criteria and alternatives in the structure and be assigned priorities which are compatible with the intuition.***

This axiom demands that all alternatives should be included in the decision making process utilizing the Analytical Hierarchy Process. Different set of criterias may elicit different alternatives. In short, Harker suggests to "include everything **<u>that matters</u>** in the decision hierarchy."

Extensions

Through the years, the Analytical Hierarchy Process has undergone some scrutiny and significant modifications. Extensions have therefore been developed to cover what has been labelled "potholes". These extensions include group theory and group decision making, consistency of results, reduction of pairwise comparisons, and application in non-hierarchial situations.

Group theory. Thomas Saaty cites several articles in the last few years that point out recent trends in decision making. Saaty further states that organizational decisions are much more technically and politically complex and require frequent group decision meetings. (17:59) In fact, brainstorming and sharing ideas and insights often lead to a more complete representation and understanding of the issues than it would be possible for a single decision maker. (30:225) Inputs invariably will come from several layers of management and specialty fields. This, however, poses potential pitfalls in decision making in the group setting. Often, participants are unequal in their expertise, experience, influence, and perspective. Hence, cooperation may require the coaxing of the leader/moderator. (30:225) The Analytical Hierarchy Process takes advantage of this by assembling the group, conducting the decision making process, and subsequently, the decision makers implementing the results.

Assembling the group. The inherent complexities (i.e. differences in opinion) and uncertainties involved in the decision making process can make a cumbersome effort a frustrating task. Competing interests and limited knowledge base further complicates the process. Saaty suggests that a group should be established to represent the wide ranging interests and different management levels. By having this varied group, the process becomes one of shared responsibility from upper and lower management levels. After all, high level management often rely on the inputs and information gathered by lower level employees. As Saaty puts it, "the Analytical Hierarchy Process helps expose various levels of management to a broad range of information, views, and arguments." (17: 60) It is also important that the group is comfortable about the situation and is fully informed of the process.

Running the decision-making process. Once the group has been established, the first course of action is to establish ground-rules that dictate the direction of group sessions. Focus must be placed in the identification of an appropriate hierarchy that addresses the problem. When this is accomplished, the difficult task of obtaining comparison data between the criterias and alternatives must be achieved. This can be done two ways. Each group member can submit an entry which is then "averaged" with the other members using the geometric mean. As shown by Aczel and Saaty, "the geometric mean is the uniquely appropriate rule for combining judgments in the Analytical Hierarchy Process because it preserves the reciprocal property in the combined pairwise comparison matrix." (17: 63) Another method to generate entries is through a concensus vote. This, however, can be a time consuming effort due to differences in opinion and agendas. A positive aspect of this procedure, however, is that wide-ranging discrepancies are bridged through discussions and crossfeed. As Erkut and Moran write, "[this] process facilitates a common understanding of the meaning and significance of each criterion...[thus clarifying] misunderstandings and differences in interpretation of the data so that there is a more uniform understanding of the facts." (10:94)

Implementing the results. When the final results are generated, the group determines if the outcomes are acceptable. After all, it is they who will have to live with the decision. The group then evaluate the effort and cost to implement the prioritized outcomes. One must remember that the Analytical Hierarchy Process, like other decision making tools, allows iterations and modifications to incorporate changing environmental factors.

Consistency. Consistency is a major source of criticism for Analytical Hierarchy Process advocates. The "cut-off" rule of 10 percent has been suggested to be arbitrary. (8:249) The general rule of consistency measure is defined by

$$\mathbf{C.I. = (\lambda_{max} - N) / (N - 1)}$$

where λ_{max} is the largest eigenvalue of an N x N pairwise comparison matrix. As shown by Saaty, if a decision maker is perfectly consistent, $\lambda_{max} =$ N and C.I. = 0. However, if the decision maker has been inconsistent, $\lambda_{max} > N$ and the consistency ratio (C.R.) -- the measure of degree of inconsistency is

$$C.R. = C.I. / R.I.$$

Golden describes this measure to be formed by taking the ratio of the Consistency Index for an N x N matrix filled in by a decision maker to an average Consistency Index value (referred to as the Ratio Index) computed from 500 N x N positive reciprocal pairwise comparisons matrices with random entries using the 1 - 9 scale. (17:68) (See Figure 5) A major objection to this rationale is that the measure is unreliable with smaller matrices. Golden and Wang, however, suggest an alternative to this method which compensates for this percieved flaw by determining geometric mean vectors, arithmetic, and reference to tables. Their study explained in full detail can be found in Harker's text.

Intensity of Importance	**Definition**
1	E_i and E_j are equally important
3	E_i is moderately more imporatnt than E_j
5	E_i is strongly more imporatnt than E_j
7	E_i is very strongly more imporatnt than E_j
9	E_i is extremely more imporatnt than E_j
2,4,6,8	Intermediate values between two adjacent judgements
Reciprocals	If activity i has one of the preceeding numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i.

Figure 5. The AHP Ratio Scale and Its Description

Incomplete pairwise comparison method. This extension was developed by Patrick T. Harker to make the mechanics of the Analytical Hierarchy Process easier. This extension allows one to reduce the effort involved in the elicitation of pairwise comparisons while at the same time allowing for the redundancy which is an important part of the the methodology.

Supermatrix technique. This extension was developed to handle problems that could not be modelled as a hierarchy. This extension allows one to break out of the hierarchial structure when needed. In other words, Axiom 3 which required a hierarchial structure is relaxed. Stated differently, the weight or priorities of the criterias are dependent on the alternatives. Therefore, a system feedback exists and the Analytical Hierarchy Process would require the application of this extension.

Application

Given the above procedures, the Analytical Hierarchy Process will be applied and validated in solving Clark County's municipal solid waste dilemma in the following manner: participant identification, hierarchy developmement, data collection, weight assignment, and outcome generation.

Key participants. As mentioned above, the decision making group will consist of key personnel representing the wide variety of interests regarding different issues. This group will consist of the following individuals from the Clark County Solid Waste District Policy Committee:

1. Health Commissioner
2. Business and Industry Representative
3. Springfield City Manager
4. County Commissioner
5. Representative from Public at Large

Evaluation Criteria Development. The evaluation criteria provide a means of organizing the various types of information describing a proposed method of handling municipal solid waste. These criterias are organized in a hierarchy with the top-level criteria providing broad and logical groupings. These criterias are further broken down or subdivided into lower-level criterias that are more focused and detailed. These criterias are successively subdivided until a level is reached where individual comparisons may be generated with regard to the alternatives.

Relative importance to the evaluation criteria and alternatives. Evaluation Criteria and Alternatives will be prioritized so that some attributes will be rated "relatively" more important than others. For example, a decision maker may determine that the Social Impact regarding the construction of a solid waste disposal facility is a more important criterion than its Technical Feasibility. This "relative importance" will be determined through responses obtained from a structured set of comparative questions about the attributes of each proposal. These responses will then be evaluated with the aid of the software program *Expert Choice* developed by Decision Support Software, Inc.

Collect proposal data. Quantitative **and** qualitative data will be collected to fully characterize the different factors of the proposed facility locations. This collected data must address all important aspects of the proposals at the appropriate level of detail. Data from Clark County will be collected via questionnaire which will be used to obtain individual inputs and presented to the group for final concurrence. This approach will inevitably save time and at the same time take advantage of group dynamics should there be a huge disparity in responses.

Apply prioritization technique. From responses obtained from the Clark County Solid Waste Policy Committee, a solution will arise from the application of Decision Support Software's *Expert Choice.*

Sensitivity analysis. Once the evaluation is complete, an analysis will be conducted to determine its sensitivity to differing factors. A possible outcome may have a very close score in comparison to another option. Therefore, an exercise in sensitivity analysis is a crucial step in this modelling effort. The analysis conducted will involve dynamic, gradient, and performance sensitivities. Dynamic sensitivity illustrates the change in priorities as a result of an increase or decrease in the priority of any criterion. Gradient sensitivity reveals "trade-off" points at which if the weight of a criteria is changed, the weight of one alternative outweighs the other. Finally, performance sensitivity presents how well each alternative performs on each criterion.

Conclusion

Through a series of meetings and discussions with the Clark County Solid Waste District, a hierarchy model will be developed and posed to the Policy Commitee for review. Pairwise comparisons will be conducted to elicit quantitative and qualitative data and perceptions from the different decision makers/committee members. With the aid of *Expert Choice*, a rank order of the alternatives will be established.

IV. Analysis and Findings

The objective of this research effort is to develop a model that will determine a municipal solid waste disposal plan from a given set of alternatives for a given community. This model, based on the Analytical Hierarchy Process, is then applied and validated at Clark County, Ohio to determine its validity. Much of the concept and methodology is already explained in the preceding chapter. However, deviations from the intended methodolgy did occur and is worth mentioning in an effort to fully characterize the analysis of results.

As background information, the alternatives posed for this particular question are the following:

Incinerator -- An incinerator is proposed for construction at the current Edison electric plant in Springfield, Ohio. This incinerator has been proposed by Ogden-Martin of New Jersey and has a capacity of 1750 tons per day of municipal waste. It's expected life expectancy of 50 years should fulfill the County's municipal waste requirements.

Landfill -- A landfill is currently proposed for construction at Tremont, Ohio by Danis Corporation. It boasts a capacity of 2500 tons per day with an expected life of 25-50 years.

Transfer -- This is the present methodology of municipal solid waste disposal by the County. Various haulers transport the County's municipal solid waste to facilities by Waste Management Company (Koogler-Suburban).

Group Composition

The intended group of decision makers for the study consisted of the Clark County Solid Waste District Policy Committee. The committee is comprised of citizens that represent the various interest groups among the community. However, due to on-going litigation regarding the issues, Policy Committee members were reluctant to disclose their position in this type of forum at this particular time. Therefore, in an effort to resolve the dilemma at hand of determining which method to implement from the given options, the Clark County Solid Waste Coordinator--Ms Debra Needham--would provide her best judgment as to the weights which the Committee would have assigned to each decision element. In my discussions with Ms Needham, she indicated that she had been in close contact with the Committee during critical phases and intense deliberations regarding the municipal waste issue and that she was confident she could provide a meaningful approximation of their jugment. Therefore, Ms Needham's analysis was assumed to effectively approximate how the Committee might have used the Analytical Hierarchy Process.

Hierarchy Development

A hierarchy of the problem was developed from review of current literature, applicable regulations, and discussions and inputs from members of the Clark County

Technical Advisory Committee and certain members of the Policy Commitee. An initial hierarchy was presented to those involved for discussion and inputs. As a result, the areas of concern for the selection of a municipal solid waste disposal facility were determined to be social, environmental, and economical impacts. Each criterion are further subdivided into sub-categories as shown: (See Figure 6)

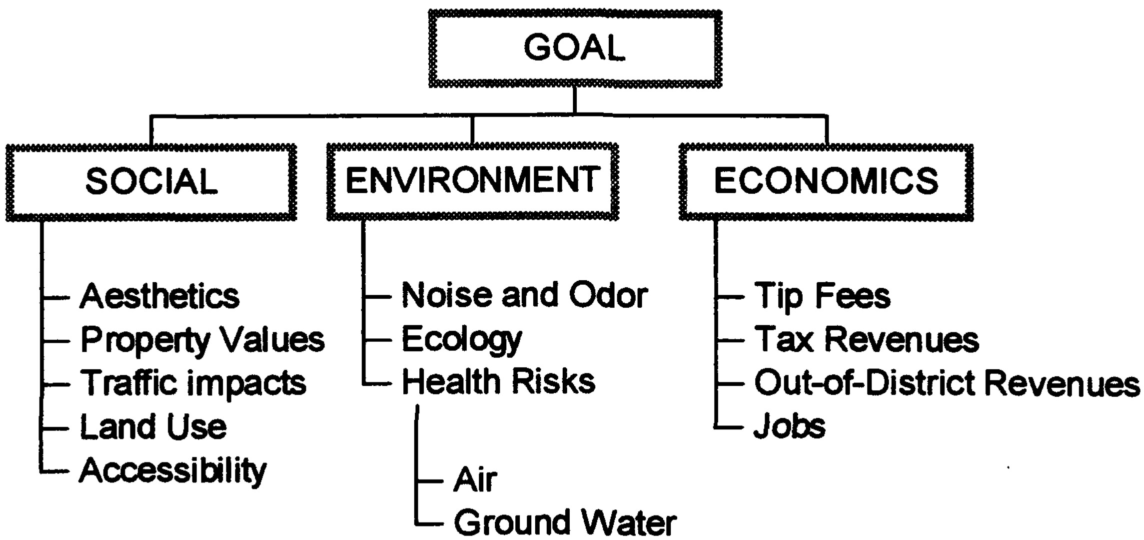

Figure 6. Hierarchy of Clark County Municipal Solid Waste Problem

Social. As discussed in the Erkut and Moran study, social factors include "all of the real and perceived societal implications" of a proposed municipal solid waste disposal facility. (10:93) The social criterion requires both quantitative and qualitative data. This particular study identifies five decision factors that contribute to the overall social impact.

Aesthetics of the particular alternative plays an important role in the overall selection of the facility. Its appeal to the community will have a significant impact whether it will or will not be socially accepted. It also includes the community attitude regarding the construction of the facility. The community characteristic's impact will vary from location to location and may either be positive or negative depending on its effect on the community's way of life. These criterion will be evaluated based on architectural renderings and public opinion, and thus a qualitative judgment.

Property value is also an important social aspect. In the example of a landfill, it has been shown that residential and commercial property located in its vicinity generally experience a 5 to 15 percent loss in value. (10:94) In light of this, several municipal solid waste disposal facility proposals include provisions to compensate neighboring areas for the perceived and anticipated loss in property values. Such compensations may include monetary provisions, additional services to local residents, committment to on-going communication with neighbors, and assistance with existing and future environmental problems. Evaluation of this critera is based on percieved lower property value and any compensensation that an alternative proposes.

Traffic impacts are concerned with the potential impacts on traffic enroute to the particular facility to include safety concerns, noise, and dust nuisances for both residential and commercial areas. This criteria also evaluates the impact of additional traffic on existing road surfaces and uses, residential streets, and heavily used roads serving commercial areas.

Land use as it is used in this model refers to the impact on the current use of the proposed area. In most cases, the construction of a certain facility prevents another type of development. In this sense, one must consider other plans for the proposed areas.

Additionally, proximity of compatible adjacent land uses (i.e. light or heavy industrial/commercial, recreation, agricultural) play a significant role in the overall decision.

Accessibility refers to the relative accessibility of the facility not only for local use but also out-of-area use. Since capacity of facilities are more likely to exceed that of the local community, access to transporters bringing in out of area revenue becomes a major issue.

Environmental. Recent trends and the growing multitude of environmental regulations has inserted environmental concerns at the forefront of today's municipal waste issues. This model identifies three criterias *in the selection of* a sound municipal solid waste plan. They include noise and odor, health risks associated with groundwater and air, and ecological impacts.

Noise and odor are inherent part of municipal solid waste disposal. One may suggest that "the farther the better" is a sound philosophy. However, when taken into consideration with other factors such as transportation costs, farther distance may not be necessarily better.

Health risk is a major concern in today's environmental issues. Whether its air, water or land, exposure to health risk factors as a result of municipal solid waste facility construction has steadily gained ground. Therefore, concern is placed on potential health effects in the air and water.

Ecological impacts deal with ecological issues such as effects on threatened and endangered species, cultural and natural resources, and area biodiversity. The facility's proximity to incompatible area such as archaeological sites, open spaces, fragile lands, biologically unique lands, historic sites included in local, state, or national registries of historic places, and possibly protected or unique farmlands may be just cause for selecting one alternative over another.

Economical. Of the three first-level criterias, economic impact perhaps is the most quantifiable criteria due to its association to hard-fact numbers. Often regarded as the bottom line in most instances, this model identifies tip fees, tax revenues, out-of-district revenues, and jobs as sub-criterias to economics.

Tip fees are the fees that a particular company collects as a result of handling municipal waste. Since most municipal solid waste disposal are privately owned, the cost to a consumer is measured by the tip fees that are paid to the operating company. These include pre-operating costs such as the cost of the land and equipment costs. Also, operating costs also play an important role. These include the cost of labor, utility, insurance and transportation.

Tax revenues encompass the daily fees that the operating company pays to the community where it is located. Although it may be suggested that this can be included in the tip fee criterion, this is broken out as a seperate entity due to its relative importance to this particular community's Policy Comittee.

Out-of-district revenues may potentially be the biggest source of revenue for the community. Due to difficulties in obtaining permits and strong opposition from most communities, many communities are willing to pay the price to have their waste brought elsewhere. This, then becomes a major factor to consider.

The number of jobs the particular industry brings to the community bears important consideration in these times where downsizing is current trend. Opportunities for community residents may sway a decision from one alternative to another.

To better understand the Process, consider the following example:

A prototype aircraft is to be selected from three proposals (A, B, and C) based on three criteria--Risk (R), Performance (P), and Schedule (S). Initial comparisons between criteria result in the following matrix.

	R	P	S
R	1	1/3	2
P	3	1	3
S	1/2	1/3	1

From this matrix, the different weights of Risk, Performance, and Schedule can be determined with the assumption that the weights are normalized and equal to 1. With that, the following equations are established:

$$1\, W_R + 1/3\, W_P + 2\, W_S = \lambda\, W_R$$

$$3\, W_R + 1\, W_P + 3\, W_S = \lambda\, W_P$$

$$1/2\, W_R + 1/3\, W_P + 1\, W_S = \lambda\, W_S$$

$$W_R + W_P + W_S = 1$$

Given four equations and four unknowns, one can arrive at the following results which indicate the weights of Risk, Performance, and Schedule, respectively:

$$W_R = .249$$

$$W_P = .593$$

$$W_S = .158$$

Further comparisons between alternatives A, B, and C with respect to each criteria are made to result in the following matrices.

R = RISK

R	A	B	C
A	1	1	2
B	1	1	2
C	1/2	1/2	1

P = PERFORMANCE

P	A	B	C
A	1	3	9
B	1/3	1	1/7
C	1/9	7	1

S = SCHEDULE

S	A	B	C
A	1	3	1/9
B	1/3	1	1/7
C	9	7	1

Applying the same concept to the criteria matrices, one can determine the weights of each alternative with respect to the criteria.

Risk	**Performance**	**Schedule**
$V_R^A = 0.4$	$V_P^A = 0.4$	$V_S^A = 0.4$
$V_R^B = 0.4$	$V_P^B = 0.4$	$V_S^B = 0.4$
$V_R^C = 0.2$	$V_P^C = 0.2$	$V_S^C = 0.2$

Respective weights are then applied to its respective criteria to determine the best alternative.

$$V_A = 0.249V_R^A + 0.593V_P^A + 0.158V_S^A = 0.537$$

$$V_B = 0.249V_R^B + 0.593V_P^B + 0.158V_S^B = 0.161$$

$$V_C = 0.249V_R^C + 0.593V_P^C + 0.158V_S^C = 0.302$$

The above example indicates that Alternative A is preferred over Alternative C which in turn is preferred over Alternative B.

Results

Inputs from the Policy Committee members were aggregated to produce a group input and with the aid of *Expert Choice*, the following weights were established to produce the following results:

Transfer	***.405***
Incinerator	***.312***
Landfill	***.283***

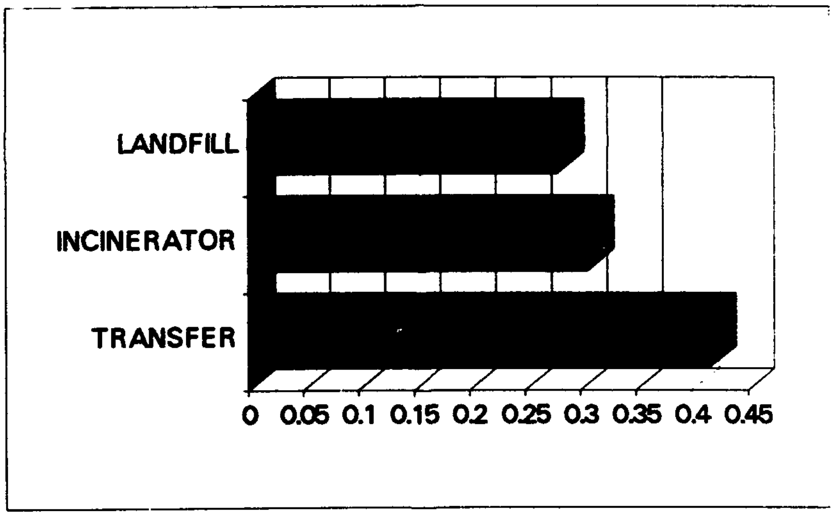

Figure 7. Priority of Alternatives

The results indicate, from an ordinal standpoint, that the current method of disposing waste should be continued based on the evaluation criterias established in the model and perceived inputs from the decision makers. Furthermore, it was determined that the economic criteria had a weight of .511 in contrast to the other two, social and environmental, which had weights of .297 and .193, respectively. (See Appendix)

Sensitivity Analysis

With the aid of *Expert Choice*, a sensitivity analysis was conducted to determine the sensitivity of the results due to changing weights of the criteria. From a social and environmental standpoint, it is clear that the transfer of municipal waste should be continued. This was expected because liabilities associated with municipal solid waste facilities are transferred within acceptable economical costs. From an economical stabdpoint, however, the results indicate that as the weight of the economic factor increases, the incinerator option should be considered. It is important to note that as the weight of the criteria increases, the results point in the direction of using a landfill.

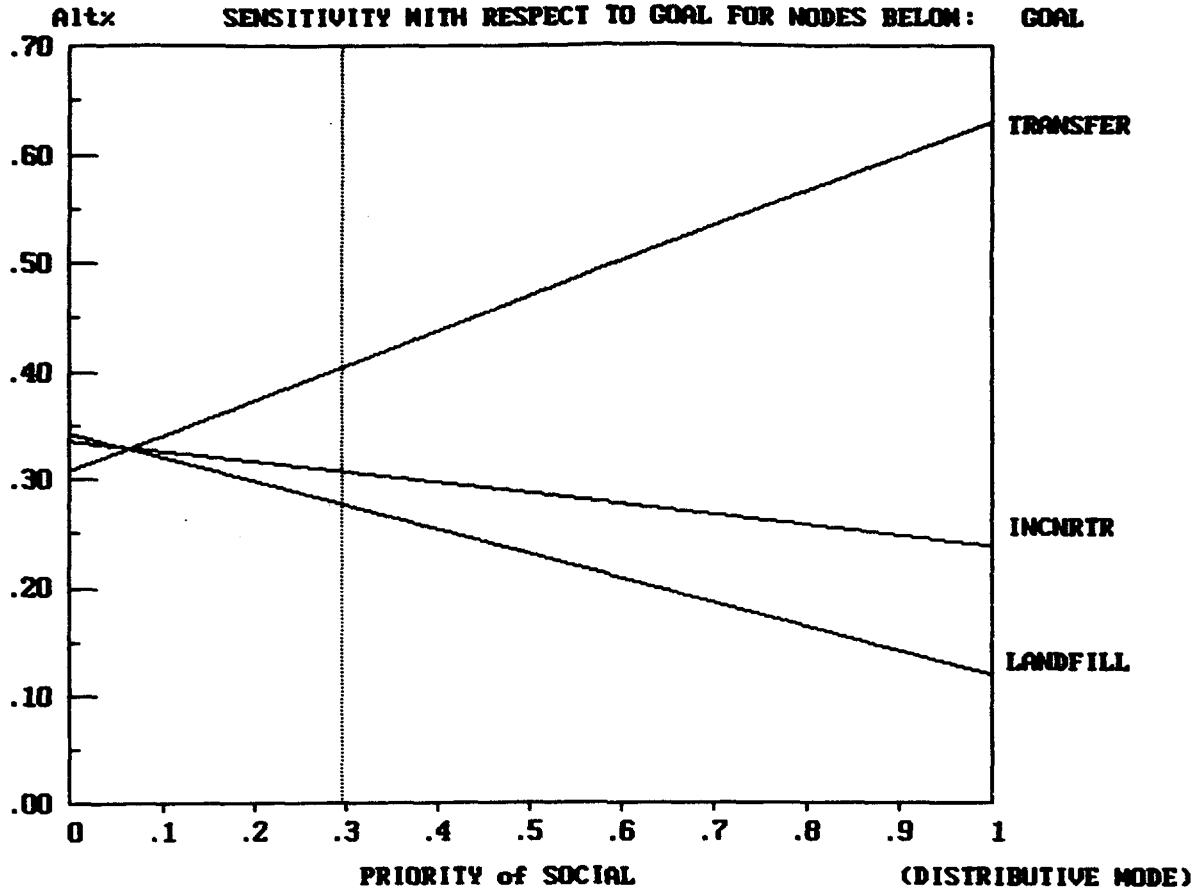

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Figure 8. Sensitivity Analysis With Respect to Goal and Social

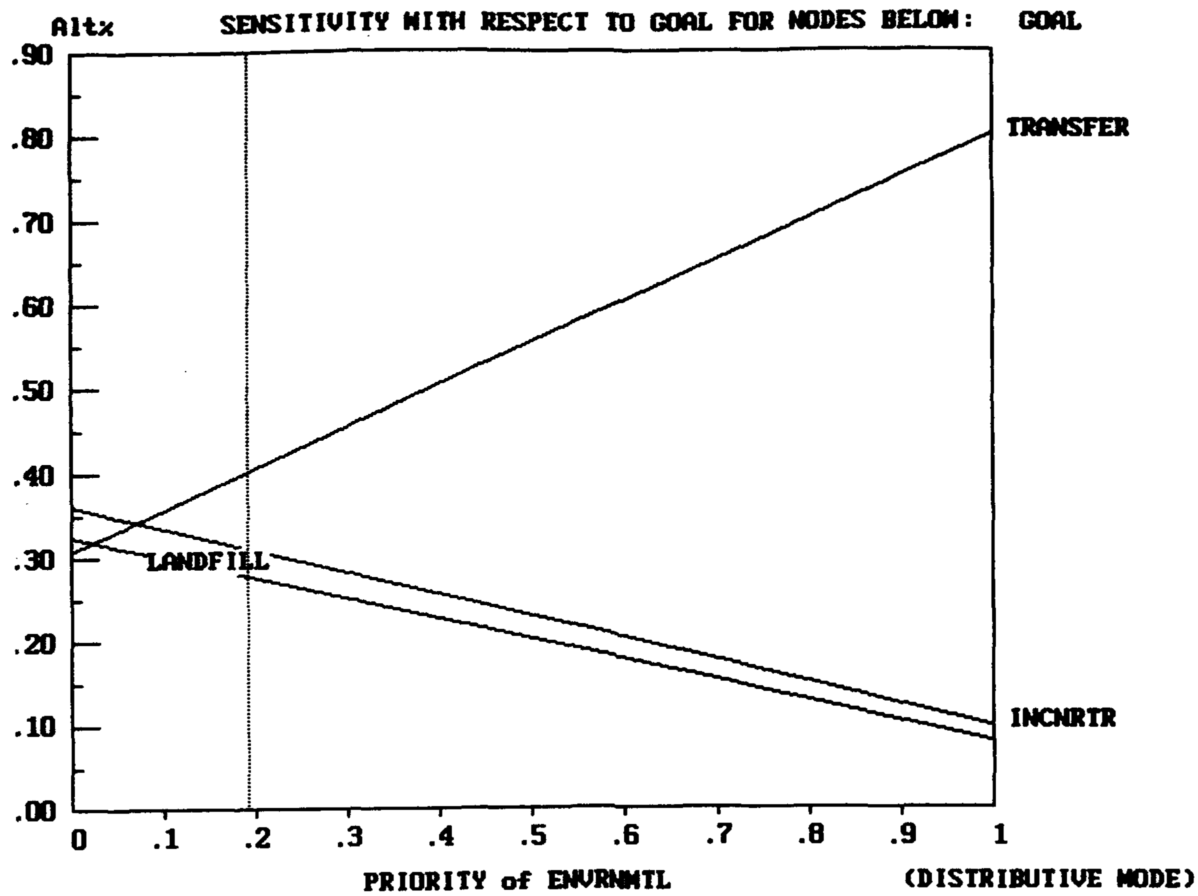

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Figure 9. Sensitivity Analysis With Respect to Goal and Environmental

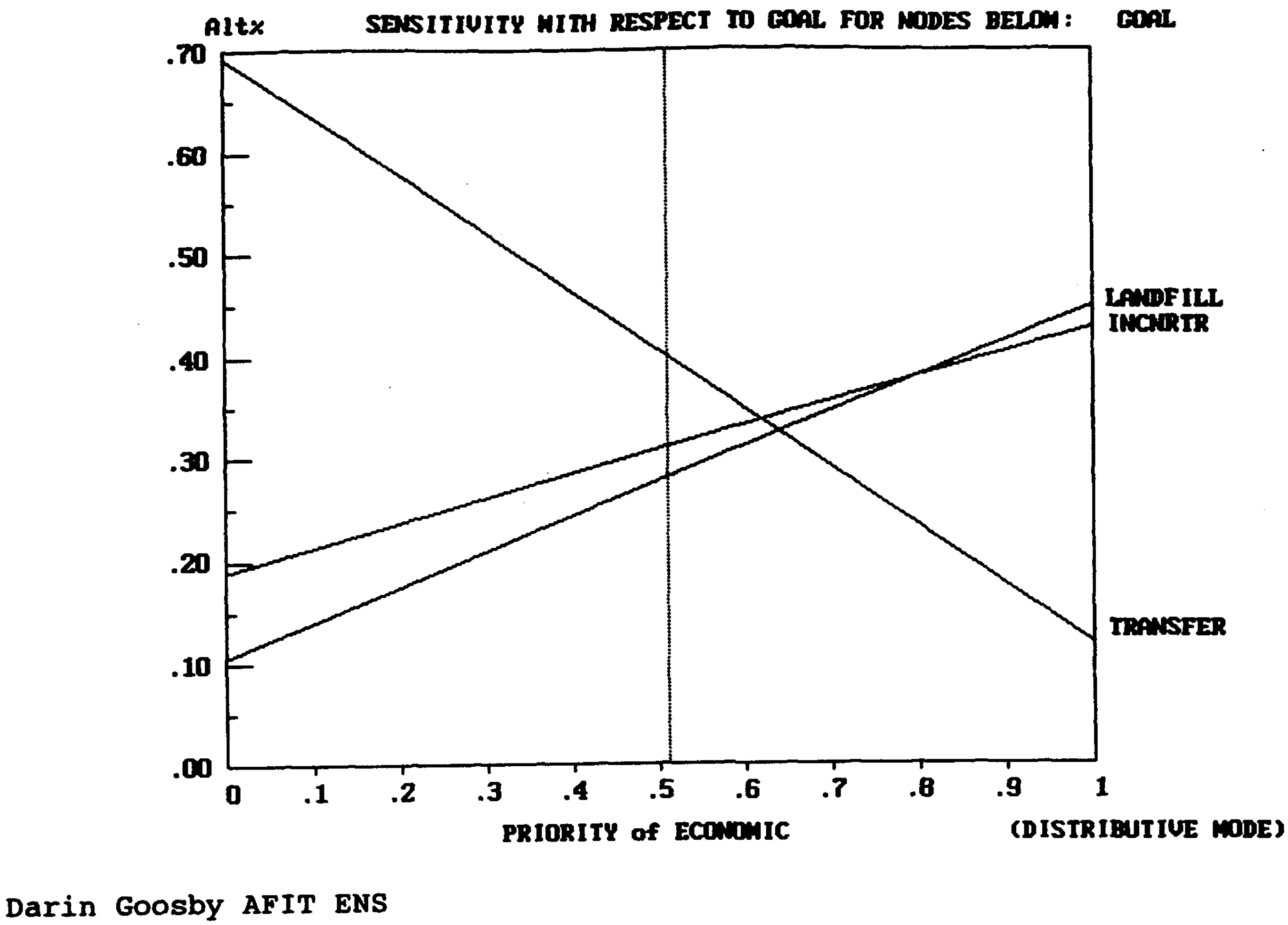

Figure 10. Sensitivity Analysis With Respect to Goal and Economics

AGGREGATED RESPONSES

FIRST LEVEL COMPARISONS WITH REGARD TO GOAL

SOCIAL	9	8	7	6	5	4	3	**2**	1	2	3	4	5	6	7	8	9	ENVIRONMENTAL
SOCIAL	9	8	7	6	5	4	3	2	1	**2**	3	4	5	6	7	8	9	ECONOMIC
ENVIRONMENTAL	9	8	7	6	5	4	3	2	1	**2**	3	4	5	6	7	8	9	ECONOMIC

SECOND LEVEL COMPARISONS WITH REGARD TO SOCIAL

AESTHETICS	9	8	7	6	5	4	3	2	1	**2**	3	4	5	6	7	8	9	PROPERTY VALUE
AESTHETICS	9	8	7	6	5	4	3	2	1	2	3	**4**	5	6	7	8	9	TRAFFIC IMPACT
AESTHETICS	9	8	7	6	5	4	3	2	1	**2**	3	4	5	6	7	8	9	LAND USE
AESTHETICS	9	8	7	6	5	4	3	2	1	2	3	**4**	5	6	7	8	9	ACCESSIBILITY
PROPERTY VALUE	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	TRAFFIC IMPACT
PROPERTY VALUE	9	8	7	6	5	4	3	**2**	1	2	3	4	5	6	7	8	9	LAND USE
PROPERT VALUE	9	8	7	6	5	4	3	2	1	**2**	3	4	5	6	7	8	9	ACCESSIBILITY
TRAFFIC IMPACT	9	8	7	6	5	4	3	**2**	1	2	3	4	5	6	7	8	9	LAND USE
TRAFFIC IMPACT	9	8	7	6	5	4	3	**2**	1	2	3	4	5	6	7	8	9	ACCESSIBILITY
LAND USE	9	8	7	6	5	4	3	2	1	**2**	3	4	5	6	7	8	9	ACCESSIBILITY

SECOND LEVEL COMPARISONS WITH REGARD TO ENVIRONMENT

NOISE AND ODOR	9	8	7	6	5	4	3	2	1	2	3	4	5	**6**	7	8	9	HEALTH RISK
NOISE AND ODOR	9	8	7	6	5	4	3	2	1	**2**	3	4	5	6	7	8	9	ECOLOGY
HEALTH RISK	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	ECOLOGY

SECOND LEVEL COMPARISONS WITH REGARD TO ECONOMIC

TIP FEES	9	8	7	6	5	4	3	**2**	1	2	3	4	5	6	7	8	9	TAX REVENUES
TIP FEES	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	EXTERNAL REV
TIP FEES	9	8	7	6	5	4	3	**2**	1	2	3	4	5	6	7	8	9	JOBS
TAX REVENUES	9	8	7	6	5	4	3	**2**	1	2	3	4	5	6	7	8	9	EXTERNAL REV
TAX REVENUES	9	8	7	6	5	4	3	2	1	**2**	3	4	5	6	7	8	9	JOBS
EXTERNAL REV	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	JOBS

THIRD LEVEL COMPARISONS WITH REGARD TO SOCIAL AND...

Aesthetics

LANDFILL	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER

Property Values

LANDFILL	9	8	7	6	5	4	3	**2**	1	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER

Traffic Impacts

LANDFILL	9	8	7	6	5	4	3	2	1	**2**	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER

Land Use

LANDFILL	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER

Accessibility

LANDFILL	9	8	7	6	5	4	3	2	1	2	3	**4**	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	**2**	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER

THIRD LEVEL COMPARISONS WITH REGARD TO ENVIRONMENT AND...

Noise and Odor

LANDFILL	9	8	7	6	5	4	3	**2**	1	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER

Health Risk Impacts

GROUNDWATER	9	8	7	6	5	4	3	2	1	**2**	3	4	5	6	7	8	9	AIR

Groundwater

LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	**6**	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER

Air

LANDFILL	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER

Ecology

LANDFILL	9	8	7	6	5	4	3	2	1	**2**	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER

THIRD LEVEL COMPARISONS WITH REGARD TO ECONOMICS AND...

Tip Fees

LANDFILL	9	8	7	**6**	5	4	3	2	1	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	**4**	3	2	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	**2**	3	4	5	6	7	8	9	TRANSFER

Tax Revenues

LANDFILL	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	9	8	7	**6**	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER

Out-of-District Revenues

LANDFILL	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	**7**	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	9	8	**7**	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER

Jobs

LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	9	**8**	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER

V. Conclusions and Recommendations

Overview

The purpose of this research was to develop a model to assist decision makers engaged in the management of municipal solid waste. This model was based on the Analytical Hierarchy Process to rank potential site and facility alternatives. This chapter states how this objective was accomplished. Conclusions are then drawn upon the research findings, followed by Contributions, Insights, and Recommendation for further research.

Summary

During the development of this model to aid decision makers in the selection of a solid waste disposal method, a review of the salient features of municipal solid waste and multicriteria decision making techniques were performed. After review of literature in these topics, the Analytical Hierarchy Process was determined to best meet the established needs of public sector decision making in solid waste management. A model was then developed based on this concept by incorporating data gathered from the literature and inputs by the decision makers.

Conclusions and Contributions

In this study, an approach was developed and presented to deal with selecting a facility and method of disposing municipal solid waste. The study identified three key factors in the multicriteria decision making problem -- social, economical, and environmental. This approach was based on the Analytical Hierarchy Process, which is a useful tool for multicriteria decision making.

Overall, the Analytical Hierarchy Process met the objectives of this research and the expectations of the Clark County Solid Waste District. More importantly, this study demonstrates that the Analytical Hierarchy Process can be a valuable tool for modeling the municipal solid waste dilemma, especially in the public sector because it gives decision makers a scientific method that can help analyze the complex location problem. A drawback, however, is the inability of the model to be generalized so it may be applied to other municipalities. A municipality must accept the hierarchy in order for this model to be applied.

Insights and Recommendations

A research effort is not complete of course without its share of criticism. Such volley of criticism is exemplified through a series of articles published in the March 1990 issue of **Management Science**. This issue displayed a barrage of opinions and positions criticizing and advocating the Analytical Hierarchy Process. These exchange of articles were both insightful and amusing. One can only ask the question "how can two groups of people, well-educated and well-respected in their own rite, be at two opposite extremes?" Loyalty is a major contributor. An analogy can be made with regard to what is the best "word processor" in the computer industry. Nonetheless, it is important to underscore key points and perhaps obstacles encountered during this particular study.

Facility siting of a municipal solid waste involve a two-step process. The first step determines a location for various alternatives. Once options are generated, a decision is required as to which method and facility should be selected based on different established criteria. I contend these as distinct phases because of the differences and uniqueness of their criteria in the decision problem. As mentioned previously, this study does not discuss the first phase. Research should be conducted on existing and potential alternative generation techniques for facility locations which include pollution models dealing with groundwater and plume dispersions.

The second phase determines the appropriate method from the generated options. This involves a hierarchy consisting of data and facts found in the literature regarding obnoxious facilities. In addition, inputs from the community strongly dictated how the hierarchy was structured. Despite the intent to develop a "generic" model to depict the decision problem, a community's character will almost always, in my opinion, determine the structure of the hierarchy. Each community is unique and thus will have varying concerns and agendas. Therefore, a further refinement of the model for specific communities is recommended.

Depending on the hierarchy developed, the number of pairwise comparisons may vary from "relatively few" to "extensive". The number of comparisons tackled in this study totalled 107 for each decision maker. Since Ms Needham took the role of the decision makers, she took the task of answering 535 comparisons. This is an extensive undertaking considering the amount of information required to elicit responses for each comparison. Despite Ms Needham's success in the challenge as depicted by her overall consistency, the assessment of the process can be described as "awkward" and "cumbersome" with regard to the number of comparisons. This was particularly true when the evaluated criteria dealt with qualitative issues. These problems, however, might not have been encountered if the decision makers themselves made the judgments rather than Ms Needham taking their role. Therefore, further study should be conducted to include committment and actual participation of actual decision makers. This process will thus facilitate group discussion and group dynamics. Also, study should be conducted to examine methods of reducing the number of pairwise comparisons other than the reciprocity axiom. Potential approaches may include reduction of criteria and alternatives through interactive approaches with decision makers.

This process also has potential application in the Environmental Impact Assessment Program(EIAP). Due to its qualitative nature and the assignment of weights that is generally required for different criteria, a study should be conducted to determine its application in the process.

Finally, further research may be conducted to determine the relationship, should it exist, between the Analytical Hierarchy Process and Utility Theory. The two schools of thought have gone to great extent to prove and disprove each other...so much that the literature appear to be the forum of philosophical battles.

In summary, this study demonstrates the application of the Analytical Hierarchy Process to determine and site a municipal solid waste disposal facility. The Analytical Hierarchy Process is one of several methods to accomplish this task. The process shows appeal in its ability to deal with qualitative information and relative ease of use. Arguments can be made for or against the method. However, we must never lose sight of the goal -- the continued effort to aid the general public, specifically decision makers, in arriving at justifiable and sound decisions.

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Vita

Captain Dimasalang(DJ) F. Junio was born on 22 August 1964 in Baguiou City, Philippines. In 1972, Captain Junio's family moved to Guam where he graduated from John F. Kennedy Senior High School in 1982. He received his commission and a Bachelor of Science in Civil Engineering from the United States Air Force Academy in 1986. Captain Junio's first assignment was to Vance AFB, Oklahoma and subsequently to Wright-Patterson AFB, Ohio as a Cost Analyst Officer for the Aeronautical Systems Division, Air Force Systems Command. In 1988, he transferred to the 2750th Civil Engineering Squadron, Wright-Patterson AFB, Ohio as a Design Engineer and later chosen as the squadron's Readiness Officer. In 1991, after completing Squadron Officer School (In-Residence), he was selected for the Peace SHIELD program, Logistics Support Group, Air Force Materiel Command, Riyadh, Saudi Arabia as a Construction Program Manager. Captain Junio was then selected in 1993 to attend the Graduate Engineering and Environmental Management program at the Air Force Institute of Technology. Upon graduation, he will be assigned to the Civil Engineering Directorate, Headquarters Air Combat Command, Langley AFB Virginia.

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Appendix A: Questionnaire Responses

public at large

FIRST LEVEL COMPARISONS WITH REGARD TO GOAL

SOCIAL	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	ENVIRONMENTAL
SOCIAL	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	ECONOMIC
ENVIRONMENTAL	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	ECONOMIC

SECOND LEVEL COMPARISONS WITH REGARD TO SOCIAL

AESTHETICS	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	PROPERTY VALUE
AESTHETICS	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	TRAFFIC IMPACT
AESTHETICS	9	8	7	6	5	4	3	**2**	1	2	3	4	5	6	7	8	9	LAND USE
AESTHETICS	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	ACCESSIBILITY
PROPERTY VALUE	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	TRAFFIC IMPACT
PROPERTY VALUE	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	LAND USE
PROPERT VALUE	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	ACCESSIBILITY
TRAFFIC IMPACT	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	LAND USE
TRAFFIC IMPACT	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	ACCESSIBILITY
LAND USE	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	ACCESSIBILITY

SECOND LEVEL COMPARISONS WITH REGARD TO ENVIRONMENT

NOISE AND ODOR	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	HEALTH RISK
NOISE AND ODOR	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	ECOLOGY
HEALTH RISK	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	ECOLOGY

SECOND LEVEL COMPARISONS WITH REGARD TO ECONOMIC

TIP FEES	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	TAX REVENUES
TIP FEES	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	EXTERNAL REV
TIP FEES	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	JOBS
TAX REVENUES	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	EXTERNAL REV
TAX REVENUES	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	JOBS
EXTERNAL REV	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	JOBS

THIRD LEVEL COMPARISONS WITH REGARD TO SOCIAL AND...

Aesthetics

LANDFILL	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER

Property Values

LANDFILL	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER

Traffic Impacts

LANDFILL	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER

Land Use

LANDFILL	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER

Accessibility

LANDFILL	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	**2**	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER

THIRD LEVEL COMPARISONS WITH REGARD TO ENVIRONMENT AND...

Noise and Odor

LANDFILL	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER

Health Risk Impacts

GROUNDWATER	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	AIR

Groundwater

LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER

Air

LANDFILL	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER

Ecology

LANDFILL	9	8	7	6	5	4	3	2	1	**2**	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER

THIRD LEVEL COMPARISONS WITH REGARD TO ECONOMICS AND...

Tip Fees

LANDFILL	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	TRANSFER

Tax Revenues

LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER

Out-of-District Revenues

LANDFILL	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER

Jobs

LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	**9**	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER

health commissioner

FIRST LEVEL COMPARISONS WITH REGARD TO GOAL

SOCIAL	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	ENVIRONMENTAL
SOCIAL	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	ECONOMIC
ENVIRONMENTAL	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	ECONOMIC

SECOND LEVEL COMPARISONS WITH REGARD TO SOCIAL

AESTHETICS	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	PROPERTY VALUE
AESTHETICS	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	TRAFFIC IMPACT
AESTHETICS	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	LAND USE
AESTHETICS	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	ACCESSIBILITY
PROPERTY VALUE	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	TRAFFIC IMPACT
PROPERTY VALUE	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	LAND USE
PROPERT VALUE	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	ACCESSIBILITY
TRAFFIC IMPACT	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	LAND USE
TRAFFIC IMPACT	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	ACCESSIBILITY
LAND USE	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	ACCESSIBILITY

SECOND LEVEL COMPARISONS WITH REGARD TO ENVIRONMENT

NOISE AND ODOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	HEALTH RISK
NOISE AND ODOR	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	ECOLOGY
HEALTH RISK	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	ECOLOGY

SECOND LEVEL COMPARISONS WITH REGARD TO ECONOMIC

TIP FEES	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	TAX REVENUES
TIP FEES	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	EXTERNAL REV
TIP FEES	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	JOBS
TAX REVENUES	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	EXTERNAL REV
TAX REVENUES	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	JOBS
EXTERNAL REV	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	JOBS

THIRD LEVEL COMPARISONS WITH REGARD TO SOCIAL AND...

Aesthetics

LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER

Property Values

LANDFILL	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER

Traffic Impacts

LANDFILL	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER

Land Use

LANDFILL	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER

Accessibility

LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER

THIRD LEVEL COMPARISONS WITH REGARD TO ENVIRONMENT AND...

Noise and Odor

LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER

Health Risk Impacts

GROUNDWATER	9	8	7	6	5	4	3	2	1	**2**	3	4	5	6	7	8	9	AIR

Groundwater

LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER

Air

LANDFILL	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER

Ecology

LANDFILL	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER

THIRD LEVEL COMPARISONS WITH REGARD TO ECONOMICS AND...

Tip Fees

LANDFILL	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	TRANSFER

Tax Revenues

LANDFILL	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER

Out-of-District Revenues

LANDFILL	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER

Jobs

LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	9	8	**7**	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER

business and industry

FIRST LEVEL COMPARISONS WITH REGARD TO GOAL

SOCIAL	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	ENVIRONMENTAL
SOCIAL	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	ECONOMIC
ENVIRONMENTAL	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	ECONOMIC

SECOND LEVEL COMPARISONS WITH REGARD TO SOCIAL

AESTHETICS	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	PROPERTY VALUE
AESTHETICS	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	TRAFFIC IMPACT
AESTHETICS	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	LAND USE
AESTHETICS	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	ACCESSIBILITY
PROPERTY VALUE	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	TRAFFIC IMPACT
PROPERTY VALUE	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	LAND USE
PROPERT VALUE	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	ACCESSIBILITY
TRAFFIC IMPACT	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	LAND USE
TRAFFIC IMPACT	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	ACCESSIBILITY
LAND USE	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	ACCESSIBILITY

SECOND LEVEL COMPARISONS WITH REGARD TO ENVIRONMENT

NOISE AND ODOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	HEALTH RISK
NOISE AND ODOR	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	ECOLOGY
HEALTH RISK	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	ECOLOGY

SECOND LEVEL COMPARISONS WITH REGARD TO ECONOMIC

TIP FEES	**9**	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TAX REVENUES
TIP FEES	**9**	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	EXTERNAL REV
TIP FEES	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	JOBS
TAX REVENUES	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	EXTERNAL REV
TAX REVENUES	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	JOBS
EXTERNAL REV	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	JOBS

THIRD LEVEL COMPARISONS WITH REGARD TO SOCIAL AND...

Aesthetics

LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER

Property Values

LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER

Traffic Impacts

LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER

Land Use

LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER

Accessibility

LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER

THIRD LEVEL COMPARISONS WITH REGARD TO ENVIRONMENT AND...

Noise and Odor

LANDFILL	9	8	7	6	5	4	3	2	1	**2**	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER

Health Risk Impacts

GROUNDWATER	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	AIR

Groundwater

LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER

Air

LANDFILL	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER

Ecology

LANDFILL	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER

THIRD LEVEL COMPARISONS WITH REGARD TO ECONOMICS AND...

Tip Fees

LANDFILL	9	8	7	**6**	5	4	3	2	1	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	TRANSFER

Tax Revenues

LANDFILL	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER

Out-of-District Revenues

LANDFILL	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	**9**	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	**9**	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER

Jobs

LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER

Springfield city manager

FIRST LEVEL COMPARISONS WITH REGARD TO GOAL

SOCIAL	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	ENVIRONMENTAL
SOCIAL	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	ECONOMIC
ENVIRONMENTAL	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	ECONOMIC

SECOND LEVEL COMPARISONS WITH REGARD TO SOCIAL

AESTHETICS	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	PROPERTY VALUE
AESTHETICS	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	TRAFFIC IMPACT
AESTHETICS	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	LAND USE
AESTHETICS	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	ACCESSIBILITY
PROPERTY VALUE	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	TRAFFIC IMPACT
PROPERTY VALUE	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	LAND USE
PROPERT VALUE	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	ACCESSIBILITY
TRAFFIC IMPACT	9	8	7	6	5	4	3	**2**	1	2	3	4	5	6	7	8	9	LAND USE
TRAFFIC IMPACT	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	ACCESSIBILITY
LAND USE	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	ACCESSIBILITY

SECOND LEVEL COMPARISONS WITH REGARD TO ENVIRONMENT

NOISE AND ODOR	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	HEALTH RISK
NOISE AND ODOR	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	ECOLOGY
HEALTH RISK	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	ECOLOGY

SECOND LEVEL COMPARISONS WITH REGARD TO ECONOMIC

TIP FEES	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	TAX REVENUES
TIP FEES	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	EXTERNAL REV
TIP FEES	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	JOBS
TAX REVENUES	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	EXTERNAL REV
TAX REVENUES	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	JOBS
EXTERNAL REV	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	JOBS

THIRD LEVEL COMPARISONS WITH REGARD TO SOCIAL AND...

Aesthetics

LANDFILL	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER

Property Values

LANDFILL	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER

Traffic Impacts

LANDFILL	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER

Land Use

LANDFILL	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER

Accessibility

LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	TRANSFER
INCINERATOR	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	TRANSFER

THIRD LEVEL COMPARISONS WITH REGARD TO ENVIRONMENT AND...

Noise and Odor

LANDFILL	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER

Health Risk Impacts

GROUNDWATER	9	8	7	6	5	4	3	**2**	1	2	3	4	5	6	7	8	9	AIR

Groundwater

LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER

Air

LANDFILL	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER

Ecology

LANDFILL	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	TRANSFER

THIRD LEVEL COMPARISONS WITH REGARD TO ECONOMICS AND...

Tip Fees

LANDFILL	**9**	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	**7**	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	TRANSFER

Tax Revenues

LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	**9**	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER

Out-of-District Revenues

LANDFILL	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	**9**	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	**9**	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER

Jobs

LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	INCINERATOR
LANDFILL	**9**	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	**9**	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER

County Commissioner

FIRST LEVEL COMPARISONS WITH REGARD TO GOAL

SOCIAL	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	ENVIRONMENTAL
SOCIAL	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	ECONOMIC
ENVIRONMENTAL	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	ECONOMIC

SECOND LEVEL COMPARISONS WITH REGARD TO SOCIAL

AESTHETICS	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	PROPERTY VALUE
AESTHETICS	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	TRAFFIC IMPACT
AESTHETICS	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	LAND USE
AESTHETICS	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	ACCESSIBILITY
PROPERTY VALUE	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	TRAFFIC IMPACT
PROPERTY VALUE	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	LAND USE
PROPERT VALUE	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	ACCESSIBILITY
TRAFFIC IMPACT	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	LAND USE
TRAFFIC IMPACT	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	ACCESSIBILITY
LAND USE	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	ACCESSIBILITY

SECOND LEVEL COMPARISONS WITH REGARD TO ENVIRONMENT

NOISE AND ODOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	HEALTH RISK
NOISE AND ODOR	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	ECOLOGY
HEALTH RISK	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	ECOLOGY

SECOND LEVEL COMPARISONS WITH REGARD TO ECONOMIC

TIP FEES	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	TAX REVENUES
TIP FEES	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	EXTERNAL REV
TIP FEES	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	JOBS
TAX REVENUES	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	EXTERNAL REV
TAX REVENUES	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	JOBS
EXTERNAL REV	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	JOBS

THIRD LEVEL COMPARISONS WITH REGARD TO SOCIAL AND...

Aesthetics

LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER

Property Values

LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER

Traffic Impacts

LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER

Land Use

LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER

Accessibility

LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER

THIRD LEVEL COMPARISONS WITH REGARD TO ENVIRONMENT AND...

Noise and Odor

LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER

Health Risk Impacts

GROUNDWATER	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	AIR

Groundwater

LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER

Air

LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER

Ecology

LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER

THIRD LEVEL COMPARISONS WITH REGARD TO ECONOMICS AND...

Tip Fees

LANDFILL	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	TRANSFER

Tax Revenues

LANDFILL	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	**9**	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER

Out-of-District Revenues

LANDFILL	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	INCINERATOR
LANDFILL	**9**	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	**9**	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER

Jobs

LANDFILL	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	INCINERATOR
LANDFILL	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER
INCINERATOR	**9**	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	TRANSFER

Appendix B: Aggregation of Results

FIRST LEVEL COMPARISONS WITH REGARD TO GOAL

1/5	1	5	(Decision Maker #1)
1	1/5	1/5	(Decision Maker #2)
5	1/5	1/5	(Decision Maker #3)
3	1	1/3	(Decision Maker #4)
5	1	1/5	(Decision Maker #5)

Note: Geometric mean values less than 1 require determination of reciprocal to reflect inverse comparisons.

1.72	0.53	0.42
	1.90	2.37

SECOND LEVEL COMPARISONS WITH REGARD TO SOCIAL

1/5	1/5	1	1/9	1/3	3	1/5	3	1/5	1/5
1	1/5	1/5	1/5	1/3	1/3	1/3	1/3	3	3
3	1/3	2	1/3	1/3	3	3	3	3	3
1/3	1/3	1	1/3	1/3	3	1/3	5	1	1/5
1/3	1/3	1	1/3	1/3	3	3	2	1	1

0.582	0.272	0.833	0.242	0.333	1.933	0.725	1.974	1.125	0.815
1.72	3.68	1.20	4.14	3.00		1.38			1.23

SECOND LEVEL COMPARISONS WITH REGARD TO ENVIRONMENT

1/9	1/5	5
1/9	1/5	5
1/3	3	5
1/9	1/5	5
1/5	5	5

0.156	0.654	5
6.423	1.528	

SECOND LEVEL COMPARISONS WITH REGARD TO ECONOMIC

9	9	5	1/5	1/5	1/5
1/3	1/3	3	1/5	3	1
5	5	1/3	5	1/3	1/5
1/3	3	1	3	1	1/3
3	5	3	3	1	1/3
1.719	2.954	1.719	1.125	0.725	0.339
				1.38	2.954

THIRD LEVEL COMPARISONS WITH REGARD TO SOCIAL AND...

Aesthetics			Property Values			Traffic Impacts			Land Use			Accessibility		
1/3	1/9	1/9	3	1/9	1/9	1/3	1/9	1/9	3	1/9	1/9	1/3	5	9
1/5	1/9	1/9	1	1/9	1/9	1	1/9	1/9	1	1/9	1/9	1/5	3	5
1/3	1/9	1/9	5	1/9	1/9	5	1/9	1/9	5	1/9	1/9	1/3	2	5
1/3	1/9	1/9	3	1/9	1/9	1/3	1/9	1/9	5	1/9	1/9	1/3	5	7
1/3	1/9	1/9	1	1/9	1/9	1/3	1/9	1/9	3	1/9	1/9	1/5	1/3	3
0.301	0.111	0.111	2.141	0.111	0.111	0.714	0.111	0.111	2.954	0.111	0.111	0.272	2.187	5.431
3.323	9	9		9	9	1.401	9	9		9	9	3.68		

THIRD LEVEL COMPARISONS WITH REGARD TO ENVIRONMENT AND...

Noise and Odor			Health Risk	Ground Water			Air			Ecology		
1/2	1/9	1/9	1/3	1/9	1/9	1/9	5	1/9	1/9	1	1/9	1/9
1/5	1/9	1/9	1/2	1/5	1/9	1/9	3	1/9	1/9	1/3	1/9	1/9
1/3	1/9	1/9	1	1/5	1/9	1/9	3	1/9	1/9	1/2	1/9	1/9
1	1/9	1/9	1/2	1/5	1/9	1/9	3	1/9	1/9	1	1/9	1/9
1/3	1/9	1/9	2	1/5	1/9	1/9	3	1/9	1/9	1	1/9	1/9
0.407	0.111	0.111	0.699	0.178	0.111	0.111	3.323	0.111	0.111	0.699	0.111	0.111
2.46	9	9	1.431	5.624	9	9		9	9	1.431	9	9

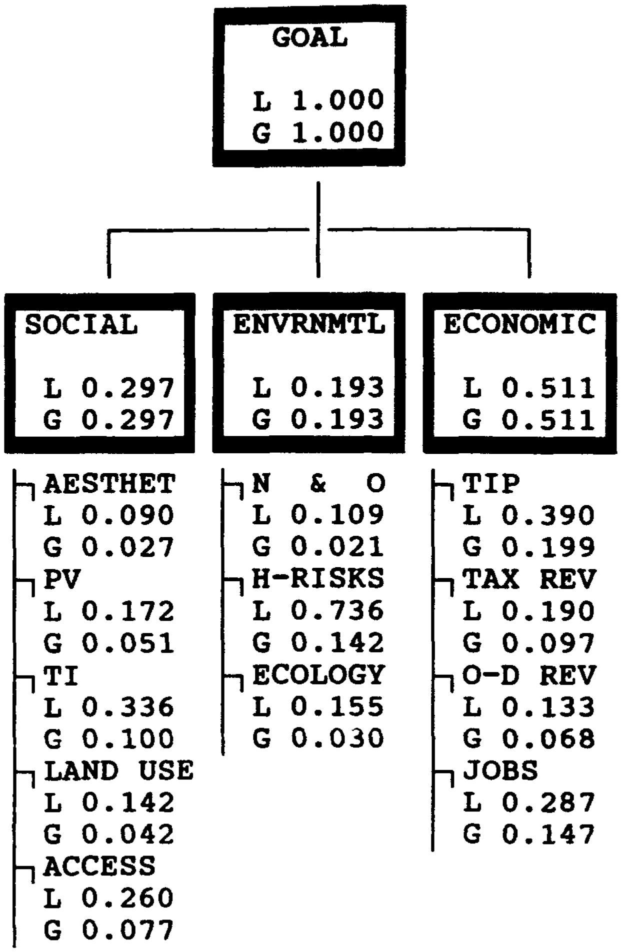
THIRD LEVEL COMPARISONS WITH REGARD TO ECONOMICS AND...

Tip Fees			*Tax Revenues*			*Out-of-District Revenues*			*Jobs*		
6	3	1/3	1	5	5	1	9	9	1/5	3	5
5	5	1/3	1/3	5	5	1	5	5	1/5	5	7
5	3	1/5	1/5	5	5	1	5	5	1/5	5	9
5	3	3	1/3	5	9	1	9	9	1/5	5	9
9	7	1/5	1/5	5	9	1	9	9	1/5	9	9
5.833	3.936	0.422 2.371	0.339 2.954	5	6.325	1	7.114	7.114	0.2 5	5.078	7.61

Appendix C: *Expert Choice* Output

C:\EC8\ECMODELS\CLARK Darin Goosby AFIT ENS

SELECT BEST MUNICIPAL SOLID WASTE DISPOSAL PLAN



ACCESS --- ACCESSIBILITY
AESTHET --- AESTHETICS
ECOLOGY --- ECOLOGY
ECONOMIC --- ECONOMIC IMPACTS
ENVRNMTL --- ENVIRONMENTAL IMPACTS
H-RISKS --- HEALTH RISKS
JOBS --- JOBS
LAND USE --- LAND USE IMPACTS
N & O --- NOISE AND ODOR
O-D REV --- OUT-OF-DISTRICT REVENUES
PV --- PROPERTY VALUES
SOCIAL --- SOCIAL IMPACTS
TAX REV --- TAX REVENUES
TI --- TRAFFIC IMPACTS
TIP --- TIP FEES

L --- LOCAL PRIORITY: PRIORITY RELATIVE TO PARENT
G --- GLOBAL PRIORITY: PRIORITY RELATIVE TO GOAL

JUDGMENTS WITH RESPECT TO
GOAL

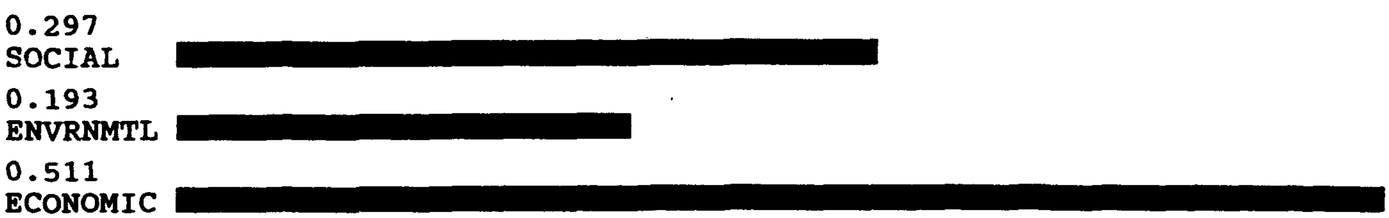
	SOCIAL	ENVRNMTL	ECONOMIC
SOCIAL		1.7	(1.9)
ENVRNMTL			(2.4)
ECONOMIC			

Matrix entry indicates that ROW element is ___
1 EQUALLY 3 MODERATELY 5 STRONGLY 7 VERY STRONGLY 9 EXTREMELY
more IMPORTANT than COLUMN element unless enclosed in parenthesis.

GOAL: SELECT BEST MUNICIPAL SOLID WASTE DISPOSAL PLAN

ECONOMIC --- ECONOMIC IMPACTS
ENVRNMTL --- ENVIRONMENTAL IMPACTS
SOCIAL --- SOCIAL IMPACTS

PRIORITIES



INCONSISTENCY RATIO = 0.009.

JUDGMENTS WITH RESPECT TO
SOCIAL < GOAL

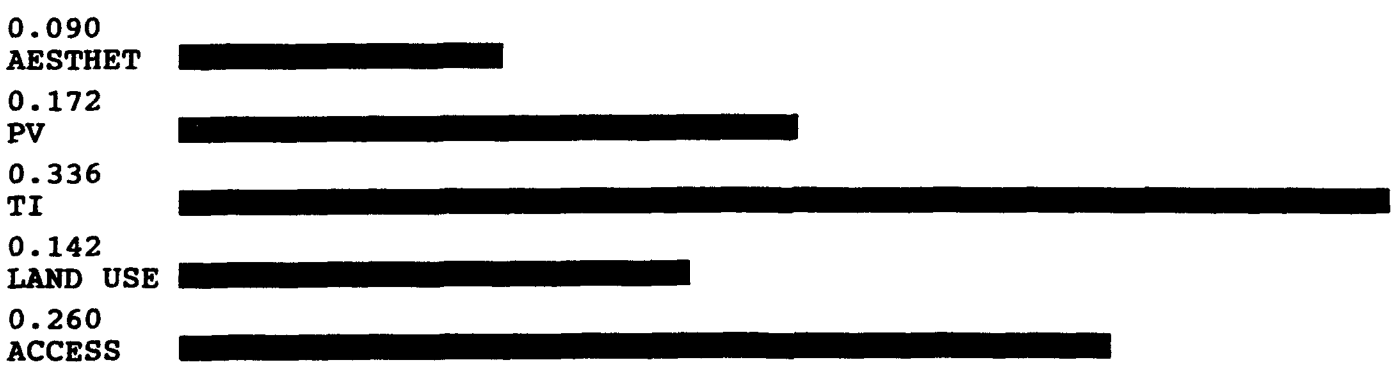
	AESTHET	PV	TI	LAND USE	ACCESS
AESTHET		(1.7)	(3.7)	(1.2)	(4.1)
PV			(3.0)	1.9	(1.4)
TI				1.9	1.1
LAND USE					(1.2)
ACCESS					

Matrix entry indicates that ROW element is ___
1 EQUALLY 3 MODERATELY 5 STRONGLY 7 VERY STRONGLY 9 EXTREMELY
more PREFERABLE than COLUMN element unless enclosed in parenthesis.

GOAL: SELECT BEST MUNICIPAL SOLID WASTE DISPOSAL PLAN

ACCESS --- ACCESSIBILITY
AESTHET --- AESTHETICS
LAND USE --- LAND USE IMPACTS
PV --- PROPERTY VALUES
SOCIAL --- SOCIAL IMPACTS
TI --- TRAFFIC IMPACTS

PRIORITIES



INCONSISTENCY RATIO = 0.039.

JUDGMENTS WITH RESPECT TO
AESTHET < SOCIAL < GOAL

	LANDFILL	INCNRTR	TRANSFER
LANDFILL		(3.3)	(9.0)
INCNRTR			(9.0)
TRANSFER			

Matrix entry indicates that ROW element is ___
1 EQUALLY 3 MODERATELY 5 STRONGLY 7 VERY STRONGLY 9 EXTREMELY
more PREFERABLE than COLUMN element unless enclosed in parenthesis.

GOAL: SELECT BEST MUNICIPAL SOLID WASTE DISPOSAL PLAN

AESTHET --- AESTHETICS
INCNRTR --- INCINERATOR
LANDFILL --- LANDFILL
SOCIAL --- SOCIAL IMPACTS
TRANSFER --- TRANSFER

PRIORITIES

INCONSISTENCY RATIO = 0.153.

JUDGMENTS WITH RESPECT TO
PV < SOCIAL < GOAL

	LANDFILL	INCNRTR	TRANSFER
LANDFILL		2.0	(9.0)
INCNRTR			(9.0)
TRANSFER			

Matrix entry indicates that ROW element is ___
1 EQUALLY 3 MODERATELY 5 STRONGLY 7 VERY STRONGLY 9 EXTREMELY
more IMPORTANT than COLUMN element unless enclosed in parenthesis.

GOAL: SELECT BEST MUNICIPAL SOLID WASTE DISPOSAL PLAN

INCNRTR --- INCINERATOR
LANDFILL --- LANDFILL
PV --- PROPERTY VALUES
SOCIAL --- SOCIAL IMPACTS
TRANSFER --- TRANSFER

PRIORITIES

INCONSISTENCY RATIO = 0.051.

JUDGMENTS WITH RESPECT TO
TI < SOCIAL < GOAL

	LANDFILL	INCNRTR	TRANSFER
LANDFILL		(1.4)	(9.0)
INCNRTR			(9.0)
TRANSFER			

Matrix entry indicates that ROW element is ___
1 EQUALLY 3 MODERATELY 5 STRONGLY 7 VERY STRONGLY 9 EXTREMELY
more IMPORTANT than COLUMN element unless enclosed in parenthesis.

GOAL: SELECT BEST MUNICIPAL SOLID WASTE DISPOSAL PLAN

INCNRTR --- INCINERATOR
LANDFILL --- LANDFILL
SOCIAL --- SOCIAL IMPACTS
TI --- TRAFFIC IMPACTS
TRANSFER --- TRANSFER

PRIORITIES

0.081
LANDFILL

0.102
INCNRTR

0.817
TRANSFER

INCONSISTENCY RATIO = 0.012.

JUDGMENTS WITH RESPECT TO
LAND USE < SOCIAL < GOAL

	LANDFILL	INCNRTR	TRANSFER
LANDFILL		2.9	(9.0)
INCNRTR			(9.0)
TRANSFER			

Matrix entry indicates that ROW element is ___
1 EQUALLY 3 MODERATELY 5 STRONGLY 7 VERY STRONGLY 9 EXTREMELY
more IMPORTANT than COLUMN element unless enclosed in parenthesis.

GOAL: SELECT BEST MUNICIPAL SOLID WASTE DISPOSAL PLAN

INCNRTR --- INCINERATOR
LAND USE --- LAND USE IMPACTS
LANDFILL --- LANDFILL
SOCIAL --- SOCIAL IMPACTS
TRANSFER --- TRANSFER

PRIORITIES

0.128
LANDFILL

0.063
INCNRTR

0.809
TRANSFER

INCONSISTENCY RATIO = 0.122.

JUDGMENTS WITH RESPECT TO
ACCESS < SOCIAL < GOAL

	LANDFILL	INCNRTR	TRANSFER
LANDFILL		(3.7)	2.2
INCNRTR			5.4
TRANSFER			

Matrix entry indicates that ROW element is ___
1 EQUALLY 3 MODERATELY 5 STRONGLY 7 VERY STRONGLY 9 EXTREMELY
more IMPORTANT than COLUMN element unless enclosed in parenthesis.

GOAL: SELECT BEST MUNICIPAL SOLID WASTE DISPOSAL PLAN

ACCESS --- ACCESSIBILITY
INCNRTR --- INCINERATOR
LANDFILL --- LANDFILL
SOCIAL --- SOCIAL IMPACTS
TRANSFER --- TRANSFER

PRIORITIES

0.211
LANDFILL

0.680
INCNRTR

0.110
TRANSFER

INCONSISTENCY RATIO = 0.018.

JUDGMENTS WITH RESPECT TO
ENVRNMTL < GOAL

	N & O	H-RISKS	ECOLOGY
N & O		(6.4)	(1.5)
H-RISKS			5.0
ECOLOGY			

Matrix entry indicates that ROW element is ___
1 EQUALLY 3 MODERATELY 5 STRONGLY 7 VERY STRONGLY 9 EXTREMELY
more IMPORTANT than COLUMN element unless enclosed in parenthesis.

GOAL: SELECT BEST MUNICIPAL SOLID WASTE DISPOSAL PLAN

ECOLOGY --- ECOLOGY
ENVRNMTL --- ENVIRONMENTAL IMPACTS
H-RISKS --- HEALTH RISKS
N & O --- NOISE AND ODOR

PRIORITIES

INCONSISTENCY RATIO = 0.003.

JUDGMENTS WITH RESPECT TO
N & O < ENVRNMTL < GOAL

	LANDFILL	INCNRTR	TRANSFER
LANDFILL		(2.5)	(9.0)
INCNRTR			(9.0)
TRANSFER			

Matrix entry indicates that ROW element is ___
1 EQUALLY 3 MODERATELY 5 STRONGLY 7 VERY STRONGLY 9 EXTREMELY
more IMPORTANT than COLUMN element unless enclosed in parenthesis.

GOAL: SELECT BEST MUNICIPAL SOLID WASTE DISPOSAL PLAN

ENVRNMTL --- ENVIRONMENTAL IMPACTS
INCNRTR --- INCINERATOR
LANDFILL --- LANDFILL
N & O --- NOISE AND ODOR
TRANSFER --- TRANSFER

PRIORITIES

INCONSISTENCY RATIO = 0.090.

JUDGMENTS WITH RESPECT TO
H-RISKS < ENVRNMTL < GOAL

	G/W	AIR
G/W		(1.2)
AIR		

Matrix entry indicates that ROW element is ___
1 EQUALLY 3 MODERATELY 5 STRONGLY 7 VERY STRONGLY 9 EXTREMELY
more IMPORTANT than COLUMN element unless enclosed in parenthesis.

GOAL: SELECT BEST MUNICIPAL SOLID WASTE DISPOSAL PLAN

AIR --- AIR
ENVRNMTL --- ENVIRONMENTAL IMPACTS
G/W --- GROUNDWATER
H-RISKS --- HEALTH RISKS

PRIORITIES

INCONSISTENCY RATIO = 0.000.

JUDGMENTS WITH RESPECT TO
G/W < H-RISKS < ENVRNMTL < GOAL

	LANDFILL	INCNRTR	TRANSFER
LANDFILL		(5.6)	(9.0)
INCNRTR			(9.0)
TRANSFER			

Matrix entry indicates that ROW element is ___
1 EQUALLY 3 MODERATELY 5 STRONGLY 7 VERY STRONGLY 9 EXTREMELY
more IMPORTANT than COLUMN element unless enclosed in parenthesis.

GOAL: SELECT BEST MUNICIPAL SOLID WASTE DISPOSAL PLAN

ENVRNMTL --- ENVIRONMENTAL IMPACTS
G/W --- GROUNDWATER
H-RISKS --- HEALTH RISKS
INCNRTR --- INCINERATOR
LANDFILL --- LANDFILL
TRANSFER --- TRANSFER

PRIORITIES

INCONSISTENCY RATIO = 0.324.

JUDGMENTS WITH RESPECT TO
AIR < H-RISKS < ENVRNMTL < GOAL

	LANDFILL	INCNRTR	TRANSFER
LANDFILL		3.3	(9.0)
INCNRTR			(9.0)
TRANSFER			

Matrix entry indicates that ROW element is ___
1 EQUALLY 3 MODERATELY 5 STRONGLY 7 VERY STRONGLY 9 EXTREMELY
more PREFERABLE than COLUMN element unless enclosed in parenthesis.

GOAL: SELECT BEST MUNICIPAL SOLID WASTE DISPOSAL PLAN

AIR --- AIR
ENVRNMTL --- ENVIRONMENTAL IMPACTS
H-RISKS --- HEALTH RISKS
INCNRTR --- INCINERATOR
LANDFILL --- LANDFILL
TRANSFER --- TRANSFER

PRIORITIES

INCONSISTENCY RATIO = 0.153.

Verbal judgments of PREFERENCE with respect to:
ECOLOGY < ENVRNMTL < GOAL

Node: 23000

1	LANDFILL	9 8 7 6 5 4 3 2	1	█ 3 4 5 6 7 8 9	INCNRTR
2	LANDFILL	9 8 7 6 5 4 3 2	1	2 3 4 5 6 7 8 █	TRANSFER
3	INCNRTR	9 8 7 6 5 4 3 2	1	2 3 4 5 6 7 8 █	TRANSFER

1=EQUAL 3=MODERATE 5=STRONG 7=VERY STRONG 9=EXTREME

GOAL: SELECT BEST MUNICIPAL SOLID WASTE DISPOSAL PLAN

ECOLOGY --- ECOLOGY
ENVRNMTL --- ENVIRONMENTAL IMPACTS
INCNRTR --- INCINERATOR
LANDFILL --- LANDFILL
TRANSFER --- TRANSFER

PRIORITIES

0.072
LANDFILL

0.114
INCNRTR

0.814
TRANSFER

INCONSISTENCY RATIO = 0.051.

JUDGMENTS WITH RESPECT TO
ECONOMIC < GOAL

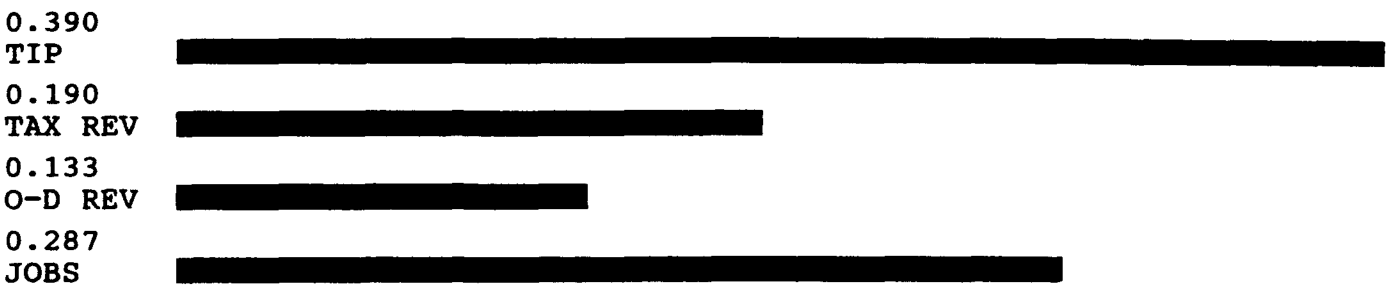
	TIP	TAX REV	O-D REV	JOBS
TIP		1.7	2.9	1.7
TAX REV			1.1	(1.4)
O-D REV				(2.9)
JOBS				

Matrix entry indicates that ROW element is ___
1 EQUALLY 3 MODERATELY 5 STRONGLY 7 VERY STRONGLY 9 EXTREMELY
more IMPORTANT than COLUMN element unless enclosed in parenthesis.

GOAL: SELECT BEST MUNICIPAL SOLID WASTE DISPOSAL PLAN

ECONOMIC --- ECONOMIC IMPACTS
JOBS --- JOBS
O-D REV --- OUT-OF-DISTRICT REVENUES
TAX REV --- TAX REVENUES
TIP --- TIP FEES

PRIORITIES



INCONSISTENCY RATIO = 0.023.

JUDGMENTS WITH RESPECT TO
TIP < ECONOMIC < GOAL

	LANDFILL	INCNRTR	TRANSFER
LANDFILL		5.8	3.9
INCNRTR			(2.4)
TRANSFER			

Matrix entry indicates that ROW element is ___
1 EQUALLY 3 MODERATELY 5 STRONGLY 7 VERY STRONGLY 9 EXTREMELY
more IMPORTANT than COLUMN element unless enclosed in parenthesis.

GOAL: SELECT BEST MUNICIPAL SOLID WASTE DISPOSAL PLAN

ECONOMIC --- ECONOMIC IMPACTS
INCNRTR --- INCINERATOR
LANDFILL --- LANDFILL
TIP --- TIP FEES
TRANSFER --- TRANSFER

PRIORITIES

INCONSISTENCY RATIO = 0.024.

JUDGMENTS WITH RESPECT TO
TAX REV < ECONOMIC < GOAL

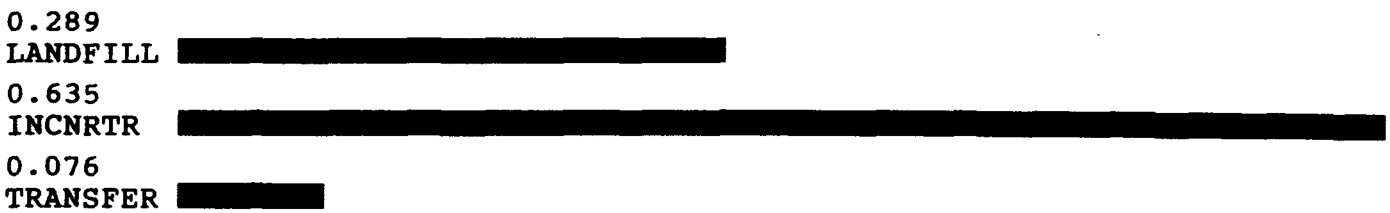
	LANDFILL	INCNRTR	TRANSFER
LANDFILL		(2.9)	5.0
INCNRTR			6.3
TRANSFER			

Matrix entry indicates that ROW element is ___
1 EQUALLY 3 MODERATELY 5 STRONGLY 7 VERY STRONGLY 9 EXTREMELY
more IMPORTANT than COLUMN element unless enclosed in parenthesis.

GOAL: SELECT BEST MUNICIPAL SOLID WASTE DISPOSAL PLAN

ECONOMIC --- ECONOMIC IMPACTS
INCNRTR --- INCINERATOR
LANDFILL --- LANDFILL
TAX REV --- TAX REVENUES
TRANSFER --- TRANSFER

PRIORITIES



INCONSISTENCY RATIO = 0.074.

JUDGMENTS WITH RESPECT TO
O-D REV < ECONOMIC < GOAL

	LANDFILL	INCNRTR	TRANSFER
LANDFILL		1.0	7.1
INCNRTR			7.1
TRANSFER			

Matrix entry indicates that ROW element is ___
1 EQUALLY 3 MODERATELY 5 STRONGLY 7 VERY STRONGLY 9 EXTREMELY
more PREFERABLE than COLUMN element unless enclosed in parenthesis.

GOAL: SELECT BEST MUNICIPAL SOLID WASTE DISPOSAL PLAN

ECONOMIC --- ECONOMIC IMPACTS
INCNRTR --- INCINERATOR
LANDFILL --- LANDFILL
O-D REV --- OUT-OF-DISTRICT REVENUES
TRANSFER --- TRANSFER

PRIORITIES

0.467
LANDFILL

0.467
INCNRTR

0.066
TRANSFER

INCONSISTENCY RATIO = 0.000.

JUDGMENTS WITH RESPECT TO
JOBS < ECONOMIC < GOAL

	LANDFILL	INCNRTR	TRANSFER
LANDFILL		(5.0)	5.1
INCNRTR			7.6
TRANSFER			

atrix entry indicates that ROW element is ___
1 EQUALLY 3 MODERATELY 5 STRONGLY 7 VERY STRONGLY 9 EXTREMELY
ore LIKELY than COLUMN element unless enclosed in parenthesis.

GOAL: SELECT BEST MUNICIPAL SOLID WASTE DISPOSAL PLAN

CONOMIC --- ECONOMIC IMPACTS
NCNRTR --- INCINERATOR
OBS --- JOBS
ANDFILL --- LANDFILL
RANSFER --- TRANSFER

PRIORITIES

.216
ANDFILL

.721
NCNRTR

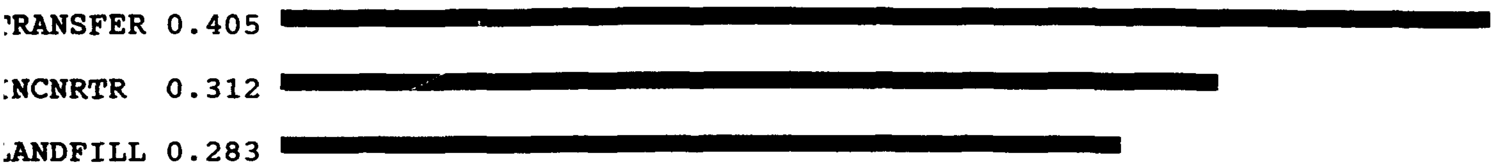
.063
RANSFER

INCONSISTENCY RATIO = 0.158.

SELECT BEST MUNICIPAL SOLID WASTE DISPOSAL PLAN

Synthesis of Leaf Nodes with respect to GOAL
DISTRIBUTIVE MODE

OVERALL INCONSISTENCY INDEX = 0.04



INCNRTR --- INCINERATOR
LANDFILL --- LANDFILL
TRANSFER --- TRANSFER

REPORT DOCUMENTATION

1. AGENCY USE ONLY (Leave blank) | 2. REPORT DATE September 1994 | Master's Thesis

4. TITLE AND SUBTITLE

DEVELOPMENT OF AN ANALYTICAL HIERARCHY PROCESS (AHP) FOR THE SITING OF MUNICIPAL SOLID WASTE (MSW) FACILITIES

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AFIT/GEE/ENS/94S-02

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS

11. SUPPLEMENTARY NOTES

Approved for public release; distribution unlimited

Deciding on locations for municipal solid waste facilities is a difficult problem where qualitative criteria compete with quantitative economic and engineering criteria, in an environment that is highly political and emotional. State guidelines often describe different methodologies but fall short in offering a solution or a methodology in arriving at a solution. This study develops a decision modeling procedure, based on the Analytical Hierarchy Process (AHP), that can be used by public sector decision makers to locate and site municipal solid waste facilities. The applicability of the procedure is demonstrated at the City of Springfield, Clark County, Ohio. Research efforts included review of alternatives to dispose municipal solid waste and multicriteria decision making techniques with potential application to the problem. Due to the nature of the problem, the Analytical Hierarchy Process was selected. A hierarchy was then developed and the Clark County Solid Waste District Coordinator provided inputs that best approximated the decision maker's inputs to arrive at a solution. Final results suggest that current disposal methods of disposing waste should be continued (transfer facility). However, as cost continues to increase relative to the given alternatives, a detailed investigation is required to determine the viability of an incinerator or a landfill. in that order.

Municipal Solid Waste, Analytical Hierarchy Process, Multicriteria Decision Making 119

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